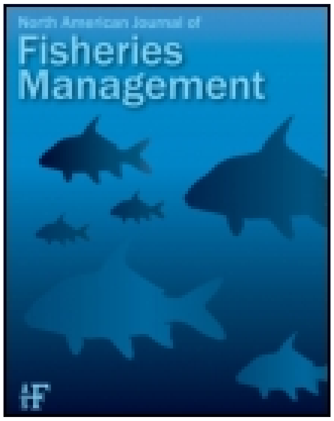

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Relative Contribution of Stocked Walleyes in Tennessee Reservoirs

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Abstract.—Since the mid-1950s, fisheries biologists with the Tennessee Wildlife Resources Agency have stocked walleyes *Stizostedion vitreum* in several tributary reservoirs of the Cumberland and Tennessee rivers to augment declining native stocks; however, the efficacy of these management actions has never been formally evaluated. The contribution of stocked walleyes in four Tennessee reservoirs was evaluated during 1999 and 2000 by marking fry and fingerlings through oxytetracycline (OTC) immersion. Stocking densities were 13–48 fingerlings/ha, and marking efficacy was high for fish marked as fry (mean = 98%; SE = 1.7%) and fingerlings (mean = 99%; SE = 0.6%). Nearly all (94–100%; N = 509) of the age-1 and age-2 walleyes collected in the four reservoirs were OTC-marked. Based on these findings, fingerling walleyes must be stocked annually to sustain the walleye populations in these tributary impoundments.

Stocking plays an integral role in the management of fisheries for walleye *Stizostedion vitreum* across North America (Goeman 2002). Although widely practiced, walleye stocking success varies considerably among locales. For example, in a review of walleye stocking case histories, Laarman (1978) reported that only one-third of all supplemental stockings were effective, and Ellison and Franzin (1992) reported success rates ranging from 32% to 50%. Although numerous studies have reported successful stocking efforts in the Midwestern United States (e.g., Lucchesi 2002; Mitzner 2002), few studies have examined the success of walleye stocking programs in the Southeast, despite the long practice of stocking in this region of North America (Hackney and Holbrook 1978).

Native walleye populations existed in the Cumberland and Tennessee rivers before the impoundment of these rivers in the early and mid-1900s (Hackney and Holbrook 1978). After tributary rivers were impounded, walleye recruitment ceased and progeny from the Great Lakes region were stocked into several reservoirs, the intent being to reestablish self-sustaining populations (Fetterolf 1957). Those stockings were successful and natural recruitment supported the fisheries for several decades. In the 1980s, biologists with the Tennessee Wildlife Resources Agency (TWRA) observed a second decline in natural recruitment in some reservoirs, coinciding with the introduction of alewives *Alosa pseudoharengus* in 1976 (Schultz 1992). Alewives were intentionally stocked into Dale Hollow and Watauga reservoirs to provide a stable forage base for lake trout *Salvelinus namaycush*. Through accidental or illegal introductions, alewives now occur in most Tennessee reservoirs supporting walleye fisheries. Declines in the abundance of lake herring *Coregonus artedi* (Eck and Wells 1987), lake whitefish *C. clupeaformis* (Hoagman 1974), yellow perch *Perca flavescens* (Brandt et al. 1987) and walleye (Schultz 1992) have coincided with the establishment of landlocked alewife populations in other locales. The specific mechanisms leading to the decline in walleye recruitment in Tennessee reservoirs were never identified, and hatchery-reared walleyes were periodically stocked to sustain these and several other populations (D. Peterson, TWRA, personal communication).

The TWRA annually stocks about 500,000 walleye fingerlings, but the efficacy of this program is uncertain. Mass-marking stocked fish via immersion in oxytetracycline (OTC) has been utilized to

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assess the contribution of hatchery-reared fish for a variety of species, including walleyes (Brooks et al. 1994; Heidinger and Brooks 1998; Isermann et al. 1999; Lucchesi 2002). The objective of this study was to assess the contribution of OTC-marked walleye fingerlings in four Tennessee reservoirs that have been stocked at varying rates and intervals since the late 1980s. Oxytetracycline marking efficacy has been variable (Brooks et al. 1994; Lucchesi 2002); therefore, a second objective was to determine marking efficacy among Southeastern hatcheries producing walleyes.

Methods

Oxytetracycline marking.—Walleye fry (3–5 d posthatch) and fingerlings reared at three Tennessee fish hatcheries (Eagle Bend, Normandy, and Springfield) and a Virginia hatchery (Buller) were marked with 500 mg OTC/L as described by Brooks et al. (1994). To fulfill stocking quotas in 1999 and 2000, the TWRA obtained additional walleye fingerlings from the Minor Clark Fish Hatchery in Kentucky. Walleyes marked as fry and stocked as fingerlings from Minor Clark and Eagle Bend hatcheries were immersed in OTC before release into rearing ponds. Some walleye fingerlings from Eagle Bend Hatchery were marked on the stocking trucks by mixing a slurry of OTC and buffering the solution to a pH of approximately 7.0 before adding it to the hauling tanks (≥590 L), as were all the walleyes from Normandy, Springfield, and Buller hatcheries. Walleyes were immersed in the OTC-solution for 6 h before being stocked in the reservoirs or rearing ponds. At each release site, total lengths (TLs) of 50 fingerlings were measured (mm). Walleye from Minor Clark were OTC marked as fry with 500 mg (1999) and 700 mg OTC/L (2000). A water sample was taken from each hatchery and analyzed for alkalinity (mg $CaCO_3$/L), total calcium (mg/L), hardness (mg/L), total magnesium (mg/L), conductivity (μS/cm) and pH.

In March 1999 and 2000, the walleye fry marked with OTC at Eagle Bend Fish Hatchery were stocked into Doakes Pond, a 2.8-ha subimpoundment on Norris Reservoir. Advanced walleye fingerlings (70–175 mm; TL) were subsequently harvested in September 1999 and 2000 from Doakes Pond and stocked into an embayment of Norris Reservoir. Because of the rearing pond's design and the manner in which fish were transferred, we were unable to determine the exact number of fingerlings released into Norris Reservoir from Doakes Pond each year. However, annual production in Doakes Pond is thought to be slight—about 1% of the number of fry stocked into the pond (M. Smith, Tennessee Wildlife Resources Agency, personal communication)—compared with the large number (≥300,000) of fingerlings stocked into Norris Reservoir. The walleye fry produced and marked at Minor Clark Hatchery were stocked into rearing ponds on site and subsequently stocked in May of each year, when other marked fingerlings were stocked.

Marking efficacy.—Marking efficacy was determined by retaining a sample ($N = 300$) of walleye fingerlings marked with OTC from each hatchery, reservoir, stocking site, and date. Following immersion in OTC, each batch of walleye fingerlings retained for the efficacy study was separately held in water recirculating tanks (568–1,136 L) for 21 d. Sagittal otoliths were then removed from approximately 40 fingerlings from each reservoir and stocking site and stored in plastic vials to prevent mark deterioration. Forty walleye fingerlings from Doakes Pond and Minor Clark Fish Hatchery (marked as fry and stocked as fingerlings) were retained for OTC mark retention before being stocked in Norris Reservoir.

Individual otoliths were mounted on a microscope slide with glue containing cyanoacrylate (Secor et al. 1991). Mounted otoliths were viewed under a Nikon Optiphot-2 compound microscope equipped with a 100-W ultraviolet light source and a Nikon B3-A filter cube (450–490-nm excitation filter, a 515-nm barrier filter, and a 510-nm dichroic mirror). In some cases, whole otoliths were wet-ground with 600-grit sandpaper when necessary to aid in OTC mark detection.

Before we examined otoliths for the marking efficacy and stocking contribution studies, a blind experiment was conducted to test mark detection. Of the 35 otoliths selected to assess mark detection, 30 were from walleyes that had been immersed in OTC and had otoliths showing an OTC mark and 5 were from fish not immersed in OTC. The reader correctly identified all of the otoliths as marked or unmarked; the OTC marks were readily distinguishable and autofluorescence was not problematic (Brooks et al. 1994).

Stocking contribution.—Marked walleyes were stocked into Norris, South Holston, and Watauga reservoirs in May 1999, and experimental gill nets were deployed the following winter (December 1999–February 2000) to collect age-1 fish. Nets were either 30.5 × 2.4 m with 13-, 19-, 25-, and 38-mm meshes or 46 × 2.4 m with 19-, 25-, and 38-mm meshes. All nets were fished overnight and

TABLE 1.—Numbers of walleye fingerlings stocked into four Tennessee reservoirs during 1999 and 2000.

Reservoir	Area (ha)	Date stocked	Number stocked	Number/ha	Mean ± SE length (mm)
Center Hill	9,224	May 2000	195,328	21	41 ± 0.7
Norris	13,680	May 1999	329,868	24	44 ± 1.1
		Sep 1999[a]	Unknown		>70[b]
		May 2000	342,465	25	43 ± 1.0
		Sep 2000[a]	Unknown		>70[b]
South Holston	3,032	May 1999	39,508	13	36 ± 0.8
		May 2000	146,360	48	33 ± 0.4
Watauga	2,572	May 1999	97,828	38	40 ± 0.9

[a] OTC-marked fry stocked into a subimpoundment of Norris Reservoir and released the following fall.
[b] Estimated mean length.

were spaced about 1 km apart along the length of each reservoir. Marked walleyes were stocked into Center Hill, Norris, and South Holston reservoirs in 2000, and sampling was directed at age-1 walleyes the following winter (December 2000–February 2001). In addition to the two styles of experimental gill nets deployed the previous year, we also set experimental nets that were 61 × 1.8 m with 19-mm and 25-mm meshes. South Holston Reservoir was also sampled in November 2001 using electrofishing gear (20 transects, 10 min each) to increase the sample of walleyes from the 2000 year-class. Stocking contribution after two growing seasons was also assessed for walleyes stocked in 1999 into Watauga and South Holston reservoirs because insufficient numbers were collected as age-1 fish. Age-2 walleyes were collected in experimental gill nets (31 × 1.8 m; 25-, 38-, 51-, 64-, and 76-mm meshes) in November and December 2000. Sagittal otoliths were removed from captured walleyes for age determination (Erickson 1983). Otoliths from walleyes hatched during years when marked fish were stocked were mounted and examined for OTC marks as previously described. The contribution of marked fish to individual year-classes was calculated by dividing the number of otoliths with an OTC mark by the total number examined. If marking efficacy or the percent contribution was less than 99%, the percent contribution was adjusted for marking efficacy.

Results

Walleye fingerlings were stocked at a rate of 13–48 fingerlings/ha. At the time of release, the average size of walleyes stocked in Center Hill, Norris, South Holston, and Watauga reservoirs ranged between 33 and 44 mm TL (Table 1). Water quality at the five fish hatcheries varied with respect to alkalinity, total calcium, total magnesium, hardness, conductivity and pH (Table 2).

Marking efficacy was high (mean = 98.4%; SE = 0.7%; 439 marked of 446 examined) for all walleyes immersed in OTC (Table 3). Despite the high marking efficacy for walleyes marked as fry (mean = 98%; SE = 1.7%) and fingerlings (mean = 99%; SE = 0.6%), OTC marks were more pronounced and consequently easier to identify in walleyes marked as fingerlings than in walleyes marked as fry.

The contribution of stocked walleyes to year-class strength in Tennessee reservoirs ranged from 94% to 100% (Table 4). Only 15 of 509 walleyes representing two year-classes in four reservoirs did not contain an OTC mark. The lowest catches were from the 1999 year-class in South Holston Reservoir, which corresponded to the lowest stocking rate in this study.

Discussion

Immersing fry and fingerling walleyes in 500 mg OTC/L for 6 h at the five Southeastern fish

TABLE 2.—Alkalinity (mg/L of $CaCO_3$), total calcium (mg/L), hardness (mg/L), total magnesium (mg/L), conductivity (μS/cm), and pH for water used at fish hatcheries where walleyes were marked with oxytetracycline in 1999 and 2000.

Hatchery	Alkalinity	Total calcium	Total magnesium	Hardness	Conductivity	pH
Buller	71	15.8	7.9	72	169	7.7
Eagle Bend	100	25.4	11.0	107	258	7.9
Minor Clark	13	14.6	5.7		162	7.8
Normandy	40	13.2	2.0	41	101	7.5
Springfield	130	46.2	7.8	148	336	7.1

TABLE 3.—Marking data and efficacy for walleyes marked as fry (FR) or fingerlings (FI) with oxytetracycline (OTC) and stocked into four Tennessee reservoirs in 1999 and 2000. Walleyes marked as fry were examined as fingerlings for OTC marks.

Reservoir	Hatchery	Number marked	Size marked	Number examined for OTC marks	Marking efficacy (%)
			1999		
Norris	Eagle Bend	500,000	FR	40	93
	Eagle Bend	179,449	FI	47	96
	Minor Clark	150,419	FR	40	100
South Holston	Eagle Bend	39,508	FI	40	100
Watauga	Eagle Bend	97,828	FI	42	98
			2000		
Center Hill	Normandy	94,802	FI	40	100
	Springfield	100,526	FI	40	100
Norris	Eagle Bend	400,000	FR	37	100
	Eagle Bend	313,564	FI	40	100
	Minor Clark	28,901	FR	40	98
South Holston	Buller	146,360	FI	40	100

hatcheries was an effective technique for assessing the contribution of stocked fish in Tennessee reservoirs. The efficacy of marking walleyes with OTC in other locales has been variable. The efficacy of marking walleye fry (2–4 d posthatch) and fingerlings in South Dakota with 500 mg OTC/L for 6 h was 50% and 100%, respectively (Lucchesi 1997); mark retention was improved by marking older walleye fry (>4 d posthatch) and increasing the concentration of OTC to 700 mg/L. The hard water (~300 mg $CaCO_3$/L) in the South Dakota study was thought to reduce the ability of walleye fry to incorporate OTC into their sagittal otoliths. Lucchesi (1997) theorized the softer water (60–100 mg/L) in the experiments conducted by Brooks et al. (1994) may have facilitated the uptake of OTC. Marking efficacy was high (mean = 99%) in the soft and moderately hard waters of the Southeastern hatcheries we examined.

Fry and fingerling walleyes were initially stocked in Tennessee reservoirs in 1954 (Fetterolf 1957) and are currently stocked in reservoirs where natural recruitment is sporadic or absent. Historically, stocking evaluations in Tennessee relied solely on noting the presence or absence of year-classes during nonstocking years (e.g., Schultz 1992) rather than a direct estimate of the contribution of stocked walleyes to the fishery (T. Churchill, TWRA, personal communication). Based on the recaptures of OTC-marked walleyes in this study, only small natural year-classes were produced in years when stocking occurred. Mechanisms leading to the decline in natural recruitment by walleyes have not been identified; however, declines in the abundance of other fish species have coincided with the expansion of alewives into new environments (Crowder 1980). Alewives have existed in Watauga Reservoir since 1976 and in South Holston Reservoir since the early 1990s, and walleye fingerlings have been stocked at irregular intervals since the mid-1980s. Alewives appeared

TABLE 4.—Stocking contribution of juvenile walleyes marked with oxytetracycline (OTC) in four Tennessee reservoirs, 1999 and 2000. Contributions were not adjusted for making efficacy unless otherwise noted.

Reservoir	Year stocked	Age at collection	Number collected	Number marked	Stocking contribution (%)
Center Hill	2000	1	124	123	99
Norris	1999	1	96	88	94[a]
	2000	1	146	144	99
South Holston	1999	1	2	2	100
	1999	2	7	7	100
	2000	1	78	77	99
Watauga	1999	1	2	2	100
	1999	2	54	51	96[b]

[a] Stocking contribution adjusted for weighted marking efficacy (98%), assuming 1% survival to the fingerling stage for OTC-marked fry stocked into Doakes Pond.

[b] Stocking contribution adjusted for marking efficacy (98%).

in Norris Reservoir in 1991, and an intensive walleye-stocking program commenced in 1997 to augment declining walleye stocks. Of the four reservoirs we studied, only Center Hill Reservoir harbored a walleye population that was self-sustaining through the 1980s and mid-1990s. However, alewives were discovered in Center Hill Reservoir during 1997, and it is expected that chronic walleye recruitment failure will eventually occur in that system if the alewife population increases.

The walleye stocking rates in Tennessee reservoirs are similar to the rates in Iowa (McWilliams and Larscheid 1992) and Missouri (Koppelman et al. 1992) but substantially lower than in South Dakota (250 fingerlings/ha; Lucchesi and Scubelek 2001). Stocking walleye fingerlings at a rate of 13–48/ha was an effective management strategy to augment limited natural recruitment in Tennessee reservoirs. In 2000, walleye yields in the four Tennessee reservoirs we studied ranged between 0.7 and 1.4 kg/ha (Malvestuto and Churchill 2000). Compared with other walleye populations in North America (Carlander 1977; D. Baccante, Ministry of Environment, Lands and Parks, unpublished data), walleye yields in Tennessee reservoirs were low to average.

Recruitment by walleyes is influenced by reservoir hydrology in some systems; strong year-classes are usually associated with high spring water levels (Kallemeyn 1987), except during years of extremely high discharges (Willis and Stephen 1987). Sammons and Bettoli (2000) reported a positive relationship between reservoir discharge and year-class strength of saugeyes (walleye × *Sauger canadense*) and four other species in Normandy Reservoir, a tributary impoundment on the lower Tennessee River. Southern strain walleyes were considered to be obligate river spawners having specific well-defined spawning grounds (Hackney and Holbrook 1978); thus, hydrology may be crucial to spawning success of other walleye strains in southern impoundments. In terms of average daily discharge in the prespawning period (January 1–March 31), 1999 and 2000 were drought years throughout the Tennessee and Cumberland River systems. During the prespawning period, 1999 and 2000 were the two driest years since 1990 at Watauga Reservoir and the third driest and driest years, respectively, at Norris Reservoir. Similarly, 2000 was the driest year since 1990 at Center Hill Reservoir, and 1999 was the driest year at South Holston Reservoir. Future stocking assessments should include a cycle of wet and dry years to further understand how natural recruitment, if any, may affect the contribution of hatchery-reared walleyes.

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