CONTRIBUTION OF STOCKED WALLEYE FINGERLINGS IN HIWASSEE RESERVOIR

Final Report

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Abstract.—Hiwassee Reservoir, a 2,460-ha impoundment on the Hiwassee River in western North Carolina, was first stocked with walleye *Sander vitreus* in the 1950s. Historically, Hiwassee Reservoir's walleye population has been self-sustaining and has not required additional stockings. However, recent establishment of blueback herring *Alosa aestivalis* has coincided with reductions and failures in walleye recruitment. In an effort to supplement natural walleye reproduction, the North Carolina Wildlife Resources Commission began an experimental stocking program in 2004. Approximately 30,000 walleye fingerlings were marked with oxytetracycline hydrochloride (OTC) and stocked annually into Hiwassee Reservoir in May 2004–2006. Sagittal otoliths from age-1 walleye were collected during October gillnetting in 2005–2007 and viewed by microscope under epifluorescent light to determine the percent contribution of stocked fingerlings to the age-1 year class. Otoliths were examined from 31 age-1 walleye captured in 2005, 70 from 2006 collections, and 123 from 2007 collections. Of those age-1 walleye, 52% bore an OTC mark in 2005, 56% in 2006, and 77% in 2007. The percentage of stocked walleye captured during three years of gillnetting exceeded the 25% management criterion used to determine stocking success. We recommend continued fingerling stocking with annual fall monitoring of the Hiwassee Reservoir walleye population to verify sustained contribution of stocked fingerlings and to determine an optimum stocking rate.

Hiwassee Reservoir's walleye *Sander vitreus* fishery has a long history as a popular recreational resource. The Hiwassee River was impounded by the Tennessee Valley Authority in 1940 to form the 2,460-ha reservoir. Although we have been unable to locate any early stocking records, walleye were stocked into the reservoir sometime before Messer (1966) collected two adults in a 1957 cove rotenone sample. Historically, Hiwassee Reservoir's walleye population has been self-sustaining and has not required additional stockings. However, the recent establishment of blueback herring *Alosa aestivalis* has coincided with reductions and failures in walleye recruitment (Wheeler et al. 2004).

Blueback herring were first collected upstream of Hiwassee Reservoir in 1996 in Chatuge Reservoir, where they were likely established by anglers using them for bait. This was a significant concern because river herrings *Alosa* spp. can survive downstream passage through dams. Mathur et al. (1996) reported high survival rates (>90%) for anadromous blueback herring passing downstream through hydropower turbines and over spillways. The ability of river herring to move downstream through hydropower dams allows them to quickly invade downstream rivers and reservoirs. The North Carolina Wildlife Resources Commission (NCWRC) first collected blueback herring from Hiwassee Reservoir in 1999.

Introductions and subsequent downstream invasions of another river herring, alewife *A. pseudoharengus*, have preceded declines in walleye recruitment in many Tennessee reservoirs. Alewives were introduced by Tennessee Wildlife Resources Agency (TWRA) into Dale Hollow and Watauga reservoirs in 1976 to provide a cold-tolerant forage for walleye and lake trout *Salvelinus namaycush*. In both reservoirs, walleye recruitment declined within four years (Schultz 1992). As alewife populations became established downstream, the relationship between alewife establishment and walleye recruitment failure repeated on other reservoirs including Center Hill, Norris, and South Holston (Vandergoot and Bettoli 2001).

Stocking is a very important management tool that many agencies use to enhance walleye populations (Fenton et al. 1996) and could be very useful following a blueback herring introduction. Stocking walleye in lakes and reservoirs on top of self-sustaining populations can suppress natural recruitment (Li et al. 1996b) and result in no changes in overall population size (Li et al. 1996a). For example, Besler (2004) found that stocking fingerling (~ 40 mm TL) walleye at a rate of 11/ha into Lake James, North Carolina, resulted in marginal contributions to age-1 abundance. However, stocking fingerling walleye into lakes and reservoirs with little or no natural reproduction may contribute to adult abundance and sustain fisheries (Li et al. 1996a; Li et al. 1996b). For example, stocking hatchery-reared fingerlings has allowed TWRA to maintain walleye fisheries in Tennessee reservoirs following alewife establishments and subsequent recruitment failures (Vandergoot and Bettoli 2003).

Following the recent blueback herring establishment in Hiwassee Reservoir, walleye recruitment has declined 60% annually between 1996 and 2002 (Wheeler et al. 2004). This investigation evaluated the effectiveness of stocking fingerling walleye to supplement Hiwassee Reservoir's declining walleye population.

Methods

Walleye brood stock were collected via electrofishing from Hiwassee Reservoir during March 2004–2006 and transported to Table Rock State Fish Hatchery, Morganton, North Carolina. Walleyes were strip-spawned at the hatchery and fertilized eggs were transferred to hatching jars. After hatching, fry were transferred to outdoor ponds and reared to approximately 40 mm total length (TL). Thirty thousand walleye fingerlings were then transferred into two 1.8-m diameter round fiberglass tanks holding a solution containing 500 mg/L of oxytetracycline hydrochloride (OTC) and 1,000 mg/L of sodium chloride with the pH buffered to 6.5–6.9 using tris (hydroxymethyl aminomethane). The fingerlings were immersed in the OTC solution for six hours. By June 1 of each year, 30,000 walleye fingerlings were stocked in open water by boat in Hiwassee Reservoir at a rate of approximately 12 fish/ha, a rate consistent with previous reservoir walleye stocking in western North Carolina. In 2004 and 2005, the fingerlings were scattered throughout the entire reservoir, and in 2006 the fingerlings were only scattered in the Hiwassee River arm. To estimate 24-h post-stocking survival, one hundred walleye fingerlings were placed in four 0.9-m^3 pens in Hiwassee Reservoir. In 2004 and 2005, the pens were constructed of polyethylene mesh and in 2006 the pens were constructed of hard plastic. The pens were collected after 24 h and percent survival of walleye fingerlings was calculated.

Mark efficacy was determined each year by retaining a sample of 400 OTC marked fingerling walleye. Following OTC immersion, the fingerlings were held in a fiberglass tank at the Table Rock State Fish Hatchery for 30 d and fed a diet of fathead minnow *Pimephales promelas* fry. Following the 30-d period, sagittal otoliths were removed from a random subsample of 100 fish. One whole otolith from each fingerling was bonded to a microscope slide using cyanoacrylate super glue and viewed whole under a Nikon Eclipse E400 compound microscope using transmitted epiflourescent light. If an OTC mark was not visible, the otolith was lightly sanded using 600-grit wet-dry sandpaper and viewed again. This process was repeated until an OTC mark was identified or the focus was reached. The presence and the intensity of OTC marks were recorded using a qualitative ordinal scale of “absent”, “fair”, “good”, and “bright” (Lorson and Mudrak 1987). To determine the contribution of the stocked fingerling walleye to the age-1 Hiwassee walleye population, gill net surveys were conducted during October 2005, 2006, and 2007 using eight permanent sites established in 2003 (Wheeler et al. 2004). Four sites were in the lower reservoir below the confluence of Beech Creek and four sites were in the upper reservoir (Figure 1). The gill net dimensions were 2.4 x 76.3 m and consisted of five 2.4 x 15.3-m panels with 25-, 32-, 38-, 44- and 51-mm bar mesh. Gill nets were set perpendicular to the shore at each of the eight sites for three consecutive 24-h periods. The near-shore end of each gill net was randomly selected. Each net was fished daily, all walleye removed, and the nets reset. All walleye were separated into site-specific bags, placed on ice, transported to the lab and frozen.

At the lab, walleye were thawed, measured (TL, mm), weighed (g), sexed, and given a unique identification number. Sagittal otoliths were removed and placed in individually coded plastic otolith vials, stored in the dark, and allowed to air-dry for 14 d. To determine the presence or absence of an OTC mark in 2005 and 2006, otoliths from age-1 walleye were bonded to a microscope slide using cyanoacrylate super glue and viewed whole under a Nikon Eclipse E400 compound microscope using transmitted epiflourescent light. The otoliths were lightly sanded using 600-grit wet-dry sandpaper until a mark was identified or the focus was reached. In 2007, the age-1 walleye otoliths were not viewed whole, but were sectioned using an Isomet saw and the focus of each otolith was examined for an OTC mark. The presence or absence of an OTC mark was recorded for each otolith and mark quality was evaluated.

Contribution of stocked walleyes to their corresponding year-classes was determined by dividing the number of marked age-1 walleyes, adjusted for OTC mark loss, by the total number of age-1 walleyes captured. Mark loss was accounted for by dividing the number of marked fish captured by the percent marking success for that year (Fielder 1992). Walleye fingerling stocking was considered successful if the contribution at age 1 was 25% or greater. We assessed the contribution at age 1 because walleye in Hiwassee Reservoir fully recruit to our sampling gear at age 1 and the linear nature of catch curves suggest that year class strength can be estimated by age-1 contribution (Wheeler et al. 2004). The success criterion was arbitrarily selected because there are no standard evaluation criteria in other documented studies to evaluate walleye stocking success.

A statistical test determined if the percent contribution of stocked walleye was greater than 25% at age 1. This survey was considered a binomial experiment (Ott 1992) because each independent trial (individual walleye) is characterized by two possible outcomes (stocked or not stocked). Thus, the estimate of the percentage of Hiwassee Reservoir walleye that were stocked can be represented by a normal approximation to the binomial probability distribution with;

$$\text{mean} = NP, \text{ and}$$

$$\text{standard deviation} = (NP(1 - P))^{1/2},$$

where N is the total number of age-1 walleye collected and P is the percentage of age-1 walleye that were stocked. An upper tailed, one-sample z-test using the normal approximation to the binomial distribution was used to test if the contribution of stocked walleye is greater than the *a priori* success criterion of 25%. Results were considered significant at a type-I error probability (α) of 0.05.

Results and Discussion

Post-stocking survival (24-h) of age-1 walleyes in Hiwassee Reservoir was relatively high at 90% in 2004, decreased to 60% in 2005 and was 85% in 2006. To compensate for the observed mortalities in 2005 and 2006, an additional 12,000 OTC marked walleyes were stocked in Hiwassee Reservoir in 2005 and an additional 4,500 in 2006 (Table 1). The low 24-h survival during the last two years may be attributed to handling stress during stocking and hot weather conditions. It is unlikely that the marking procedure affected survival because other studies have reported that OTC marking did not influence short-term survival of stocked walleyes (Peterson and Carline 1996; Besler 2004).

Mark retention of 100 walleyes held at the hatchery for 30 d was 99% in 2004. In 2005, the hatchery experienced high mortality of the fish being held for 30-d mark verification, with 100% mark retention on the remaining 16 fish (Table 2). Mark quality of the stocked fish in 2004 and 2005 was high. In 2004, 81% of the marked fish were rated as "bright", and 94% in 2005. The percentage of "fair" and "good" marks was low during both years. In 2006, mark retention and quality could not be determined because the verification sample was used for supplemental stocking in Hiwassee Reservoir to offset mortalities observed during the original stocking (Table 2). When adjusting for tag loss in 2006, we assumed that mark retention was 99% because we had experienced no more than 1% mark loss, and retention was typically 100%. Similarly, Besler (2004) reported 100% mark retention from a subsample of 90,000 walleye marked at NCWRC's Table Rock State Fish Hatchery during a three-year study using identical marking methods, and other studies using the same OTC concentration and immersion times have reported high marking success of walleyes (Brooks et al. 1994; Lucchesi 2002).

Recruitment of walleye to age 1 increased throughout the study. Total catch of age-1 walleyes in gill nets increased each year from 31 in 2005 to 123 in 2007 (Table 3). This trend is opposite to the decline in walleye recruitment to age 1 between 1996 and 2002 that Wheeler (2004) reported following blueback herring establishment in Hiwassee Reservoir. The improved recruitment of age-1 walleye was attributed to the increase in the number of stocked walleye collected each year. In 2005, 52% of the age-1 walleyes collected were OTC marked, and in 2006 and 2007 the percentages increased to 56% and 77%, respectively (Table 3). A one-tailed z-test confirmed that the percent contribution of stocked walleyes to age 1 was greater than 25% each year (2005–2007, $P \leq 0.001$).

Stocked walleye contributed significantly to the Hiwassee Reservoir population throughout the study. Although walleye stockings have yielded mixed results in other reservoirs (Ellison and Franzin 1992), the most successful walleye stocking programs occurred in systems with very low levels of recruitment (Li et al 1996a). Natural walleye recruitment has remained low in Hiwassee Reservoir since the establishment of blueback herring in 1999. Mechanisms responsible for stocking success were not determined in this study. It is likely, however, that stocking fingerlings may avoid sources of catastrophic mortality upon earlier life stages and result in more stable year class strength (Wheeler et al. 2004). Our findings suggest that walleye populations in Hiwassee Reservoir can only be maintained with continued annual fingerling stockings.

Conclusions

Stocked walleyes contributed significantly to the age-1 population in Hiwassee Reservoir and greatly exceeded the *a priori* success criterion of 25% each year. Mass-marking of walleyes with OTC was a valuable tool to effectively determine the stocking success of this program and should be used in future walleye stocking evaluations.

Recommendations

1. Continue stocking fingerling walleyes in Hiwassee Reservoir.

2. Annually monitor the age-1 population to verify sustained contribution of marked fish.

3. Determine an optimum fingerling walleye stocking rate for Hiwassee Reservoir.

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TABLE 1.—Number of walleyes stocked in Hiwassee Reservoir during spring 2004–2006, mean TL of the stocked walleyes, 24-h survival estimates, and the number of walleyes stocked to compensate for mortalities.

Year	Walleyes stocked	Mean TL (mm)	Percent 24-h survival	Supplemental walleyes stocked
2004	30,000	38.1	90	-
2005	30,000	37.5	60	12,000
2006	30,000	43.9	85	4,500

TABLE 2.—Mark retention and mark quality of age-0 walleyes held at Table Rock State Fish Hatchery. Mark retention could not be evaluated in 2006 due to lack of available test fingerlings.

		Percent by mark quality			
Year	N	Absent	Fair	Good	Bright
2004	100	1	4	14	81
2005	16	0	0	6	94
2006	0	-	-	-	-

TABLE 3.—Number of age-1 walleyes collected in fall gill net surveys (N), mean TL of age-1 walleyes collected, the number of marked walleyes collected, percent contribution to the age-1 year class, and mark qualities. Standard errors for mean TL are shown in parentheses and a 95% confidence interval is shown in parentheses for percent contribution to age 1.

					Mark quality percentages		
Sample Year	N	Mean TL (mm)	N marked	Percent contribution to age-1	Fair	Good	Bright
2005	31	401 (3.5)	16	52 (30-74)	19	31	50
2006	71	385 (2.4)	40	56 (43-69)	25	35	40
2007	123	372 (2.4)	95	77 (69-86)	28	31	41

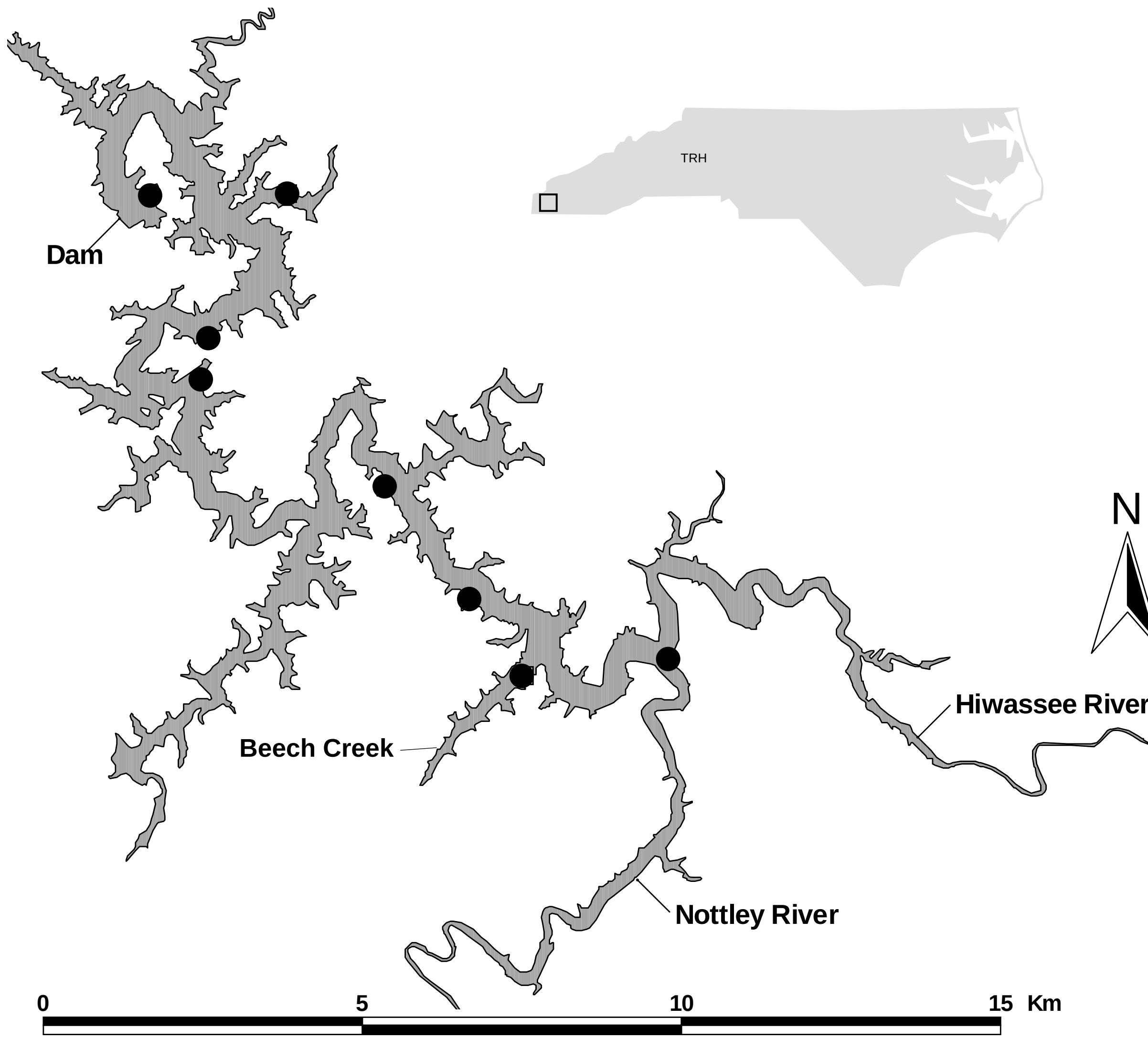

FIGURE 1.—Location of the eight gill net sites used to sample age-1 walleyes on Hiwassee Reservoir during fall 2005–2007. TRH = Location of Table Rock Hatchery.