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Initial Poststocking Mortality, Oxytetracycline Marking, and Year-Class Contribution of Black-Nosed Crappies Stocked into Tennessee Reservoirs

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Abstract.—Initial poststocking mortality, oxytetracycline mark persistence, and year-class contribution were evaluated for black-nosed crappies, a morphological variant of the black crappie *Pomoxis nigromaculatus*, stocked into Tennessee reservoirs during 1997–1999. Average initial poststocking mortality was low ($\bar{x}$ = 13%, N = 44). Lake temperature and the difference between lake and hauling tank water temperatures were significant in explaining variability in arcsine-transformed mortality estimates; however, the variability explained by these factors was low (R^2 = 0.15). Oxytetracycline immersion was a highly effective marking tool; 97–100% of all crappies treated were marked, and 99% of the marks were visible 36–110 weeks after marking. All control otoliths were correctly scored as unmarked during the evaluation, and mortality rates did not differ between marked and unmarked crappies. Year-class contribution was variable across reservoirs and was highest in Normandy Reservoir (34–93% at ages 1–3). Contribution at ages 1 and 2 was 11–24% in Woods Reservoir. Stocking did not supplement the crappie population in Lake Graham. Black-nosed crappies made up a significant portion (>50%) of the crappies harvested by anglers in Center Hill Reservoir 3 years after stocking was initiated. Conversely, black-nosed crappies made up a relatively small percentage (≤12%) of the crappies harvested in Cherokee Reservoir in the 4 years after initial stocking.

Crappies *Pomoxis* spp. represent a significant sport fishery across their range; however, the quality of individual fisheries is often variable because of inconsistent recruitment (Miller et al. 1990; Colvin 1991; Mitzner 1995). Supplemental stocking has a long history of use to improve sport fisheries, but intensive supplemental stocking to improve crappie fisheries is not common (Davin et al. 1989; Myers et al. 2000). The success of any stocking program is determined by several factors, including poststocking survival (Murphy and Kelso 1986). Survival of fish following stocking is related to many variables including prestocking and poststocking environments, fish size and condition, genetics, and handling and transportation (Mazeaud et al. 1977; Parker 1986; Williamson and Carmichael 1986; Hume and Parkinson 1988; Wallin and Van Den Avyle 1995).

In the late 1980s the Tennessee Wildlife Resources Agency (TWRA) began supplemental stocking of crappies into reservoirs in an attempt to improve crappie fisheries. From 1990 through 1999, TWRA stocked almost 7.2 million crappies in reservoirs across the state, but these stockings have not been thoroughly evaluated. The majority of crappies stocked in Tennessee are a morphological variant of the black crappie *P. nigromaculatus*, the black-nosed crappie, which is characterized by a black predorsal stripe (Buchanan and Bryant 1973). The prominent black stripe has frequently been used as a mark in perfunctory

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analyses of crappie stocking success in Tennessee reservoirs. However, black-nosed crappies naturally reproduce in these systems, and the unstriped portion of black crappies in each stocking confound the use of this mark as an evaluation tool.

Accurate assessment of a stocking program dictates that stocked fish be readily discernible from progeny spawned within a system. Numerous marking procedures have been used to segregate stocked fish from their wild counterparts, including genetic marking (Koppelman et al. 1992), fin clipping (Margenau 1992), freeze branding (Lucchesi 1997), otolith structure (Fielder 1992), microwire tags (Myers et al. 2000), and chemical marking (Brooks et al. 1994). However, large stockings often preclude the use of many such procedures. Mass-marking with tetracycline antibiotics by immersion has proven to be effective for several species (Hendricks et al. 1991; Brooks et al. 1994; Unkenholtz et al. 1997), including crappies (Conover and Sheehan 1996).

The objectives of this study were to (1) determine initial poststocking mortality of black-nosed crappies stocked into Tennessee reservoirs, (2) analyze factors regulating their initial poststocking survival, (3) evaluate persistence of oxytetracycline (OTC) marks used to identify stocked crappies, and (4) estimate the contribution of stocked fish to the crappie populations in the reservoirs.

Methods

Initial poststocking mortality.—Initial poststocking mortality was evaluated for black-nosed crappies stocked into nine large Tennessee reservoirs (>1,000 ha) and into one small impoundment (200 ha) during October to December of 1997–1999. Crappies originated from five state hatcheries: Eagle Bend, Humboldt, Morristown, Normandy, and Sugar Creek. Our study focused primarily on fish originating from Eagle Bend and Normandy hatcheries, the two hatcheries primarily responsible for producing black-nosed crappies. Stocking followed normal hatchery protocols; the following description represents generalized procedures. Crappies were reared in 0.4-ha ponds. Ponds were drained the day of stocking, and fish were confined to kettle structures for removal. Crappies were seined and dip-netted into large containers, weighed, and then placed in standard hatchery hauling tanks supplied with oxygen or agitation devices. Subsamples of fish were counted and weighed to estimate the total number of crappies harvested. Crappies were transported to the designated reservoir immediately following loading and were stocked at multiple sites having boat ramps. Tempering was used when necessary before fish were released.

The difference between hauling tank and reservoir surface water temperature was calculated for each stocking event. Handling time and hauling time (min) were recorded for each loaded tank. Handling time was defined as the period beginning with crappies being confined to the pond's kettle structures and continuing until they were all placed into hauling tanks. Hauling time represented time between completion of loading and time at release. Hauling densities (g/L) were recorded for each tank loaded. Crappies from one pond were frequently loaded into multiple hauling tanks; therefore, mean total lengths of crappies were only estimated for each pond. Total lengths (mm) of approximately 50 crappies from each pond were measured to determine the overall mean.

To determine initial poststocking mortality rates, a sample of 200−520 crappies was netted from each hauling tank before release and placed into net-pens ($1 \times 1 \times 3$ m; 1.6-mm mesh) at each stocking site. These fish were held for approximately 24 h poststocking, at which time final numbers living and dead were recorded. Mortality associated with transport of crappies to the pens and net-pen confinement conditions were assumed to be minimal and equal among samples, so multiple observations for individual tanks were averaged to obtain mortality estimates. Each hauling tank represented a single observation in mortality analyses; there were 19 stockings producing 44 individual hauling tank observations.

A stepwise multiple-linear regression model was used to evaluate the effects of nine variables on initial mortality rates. Variables were considered significant at $\alpha = 0.10$ in the regression model. Multicollinearity was assessed a priori using Pearson correlation analyses. Correlation analysis was also used to determine whether the number of crappies held in each pen significantly affected mortality rates. Initial poststocking mortality data were arcsine-transformed to improve normality. All statistical analyses were performed using Statistical Analysis System (SAS) software (SAS Institute 1996).

Stocking contribution and oxytetracycline marking.—Black-nosed crappie stockings were evaluated in Lake Graham (a small, 200-ha eutrophic reservoir constructed and managed by TWRA as a fishing lake) and in four large storage reservoirs on tributaries of the Tennessee and Cumberland rivers: Center Hill Reservoir (9,224 ha; mesotro-

TABLE 1.—Number and stocking rate of black-nosed crappies stocked into Center Hill and Cherokee reservoirs from 1990 to 1999. Black-nosed crappies were not stocked in Cherokee Reservoir before 1995, and in 1995 it received 44,100 black crappies (i.e., no predorsal stripe) in addition to those reported below.

Year	Number stocked	Stocking rate (number/ha)
Center Hill Reservoir		
1990	220,000	23.9
1991	199,814	21.7
1992	264,123	28.6
1993	124,573	13.5
1994	157,554	17.1
1995	125,105	13.6
1996	230,115	24.9
1997	227,653	24.7
1998	243,318	26.4
1999	453,121	49.1
Cherokee Reservoir		
1995	263,653	28.6
1996	371,309	30.3
1997	185,990	15.2
1998	431,667	35.2
1999	26,383	2.2

phic; mean depth, 22.1 m), Cherokee Reservoir (12,270 ha; mesotrophic; mean depth, 12.3 m), Normandy Reservoir (1,300 ha; eutrophic; mean depth, 11.2 m), and Woods Reservoir (1,600 ha; eutrophic; mean depth, 5.7 m). Center Hill, Cherokee, and Normandy reservoirs provide both hydropower and flood control, so water levels fluctuate seasonally; Woods Reservoir is a water-supply reservoir with relatively stable water levels.

Black-nosed crappies were stocked annually into Center Hill Reservoir from 1990 to 1999 and into Cherokee Reservoir from 1995 to 1999 at densities ranging from 2.2 to 49.1 crappies/ha (Table 1). Crappies stocked into these two reservoirs were not marked using OTC immersion; hence, the numbers of black-nosed crappies observed in annual creel surveys (1991–1999; TWRA 1999) were used to provide crude estimates of stocking success. Oxytetracycline marking was used to evaluate stocking success in Lake Graham, Normandy Reservoir, and Woods Reservoir. Crappies were marked following the OTC-immersion technique described in Brooks et al. (1994). Before release, crappies were held in hauling tanks for 6 h in a solution consisting of 500 mg/L OTC and approximately 300 mg/L sodium phosphate dibasic buffer. Mortality rates of OTC-marked and unmarked crappies were compared using a Wilcoxon's rank-sum test.

To determine marking efficacy for each stocked cohort, some crappies from each marking date were held for 30 d and sacrificed; sagittal otoliths were removed from subsamples of fish (N = 13–70) and examined for marks. Efficacy was estimated for the 1997 cohort stocked into Normandy Reservoir using otoliths from age-1 black-nosed crappies (known to be marked) that were collected in August 1998 rotenone samples. Mark evaluation protocol followed that described in Isermann et al. (1999).

Mark longevity was estimated for all trials and was defined as the time in weeks between marking and the time of recapture. Long-term mark retention, or the percentage of marked black-nosed crappies retaining OTC marks at time of recapture, was estimated using black-nosed crappies that were first stocked into Normandy Reservoir, when most of the fish we examined were not sexually mature. Black-nosed crappies had not been collected from Normandy Reservoir prior to initial stocking. Therefore, all age-1 and age-2 black-nosed crappies collected from the reservoir during 1997–1999 were assumed to be stocked fish.

Year-class contribution was used as a measure of stocking efficacy. Stocking dates, number stocked, stocking densities, time at recapture, and recapture gears are reported in Table 2. The use of different recapture gears was necessary due to differences in gear performance among reservoirs and because crappie catchability within individual gears varied with age. Crappies were collected from multiple sites within a reservoir with each gear. Sagittal otoliths were removed from all crappies collected in the three OTC study reservoirs. Otoliths from all crappies within year-classes that could potentially contain stocked crappies were examined using the mark detection techniques described in Isermann et al. (1999). Unmarked otoliths from white crappies *P. annularis* were used as controls during 1998 and 1999. Stocking contribution was defined as the percentage of marked fish in each year-class. Chi-square analyses were used to compare age-2 contribution estimates obtained from rotenone and electrofishing in Normandy Reservoir and to evaluate whether contribution estimates within these gears remained consistent over time in both Normandy and Woods reservoirs. Additionally, a chi-square test was used to compare contribution estimates between the 1997 and 1998 stocked crappie cohorts in Normandy Reservoir and to compare contribution between crappies stocked into Normandy and Woods reservoirs in 1998. Differences in contribution were considered significant at α = 0.10.

TABLE 2.—Stocking year (cohort), number stocked, and stocking density of oxytetracycline-marked black-nosed crappies stocked into three Tennessee impoundments between October and December. Date at recapture and recapture gears used to estimate year-class contribution are also listed.

Lake	Cohort	Number stocked	Stocking rate (number/ha)	Recapture date	Sampling gear
Graham	1998	23,000	113	Nov 1999	Electrofishing, trap nets
Normandy	1997	40,000	31	Aug 1998	Rotenone
				May 1999	Electrofishing
				Aug 1999	Rotenone
				Apr 2000	Electrofishing
	1998	66,000	50	Aug 1999	Rotenone
				Apr 2000	Electrofishing
Woods	1998	73,000	45	Oct 1999	Electrofishing
				Apr 2000	Electrofishing

Results

Initial Poststocking Mortality

Mean total length of black-nosed crappies at the time of stocking averaged 56.7 mm (SD = 6.6). Initial mortality rates were generally low; 59% were 10% or less and the average was 13% (Table 3; Figure 1). Average mortality rates did not differ (Z = 0.803; P = 0.4216) between OTC-marked (N = 15, $\bar{x}$ = 13.8%) and unmarked fish (N = 28, $\bar{x}$ = 12.4%); therefore, mortality rates from marked and unmarked samples were pooled in subsequent multiple regression analyses. No correlation existed between the number of crappies held in each pen and arcsine-transformed mortality rates (P = 0.17; df = 42).

Variables we examined for predictive value in assessing mortality included day of year (DAY), tank volume (VOL), handling time (HANDLE), hauling time (HAUL), hauling density (DENSITY), mean total length of stocked crappies (TL), reservoir water temperature (LKTEMP), tank temperature (TNTEMP), and the difference (absolute value) between these temperatures (TEMPDIF). Numerous correlations existed among these predictor variables. Consequently, multiple regression modeling was initially conducted using only LKTEM, DENSITY, and TEMPDIF as predictor variables to prevent multicollinearity. Variability in arcsine-transformed mortality was best explained by the regression equation:

$$\text{MORTALITY} = -5.03 + 1.61(\text{LKTEM}) - 2.61(\text{TEMPDIF}).$$

Only LKTEM and TEMPDIF explained significant amounts of variability in the model; however, the

TABLE 3.—Sample sizes (N) and means, standard deviations, and ranges of the initial poststocking mortality rate, hauling density (DENSITY), handling time (HANDLE), hauling time (HAUL), day of year (DAY), reservoir water temperature (LKTEMP), total number of crappies in each pen, the difference between hauling tank and reservoir water temperatures (TEMPDIF), mean total length of stocked crappies (TL), water temperature aboard hauling tanks (TNTEMP), and tank volume (VOL).

Variable	*N*	Mean	SD	Range
Mortality (%)	44	13	15.2	0–50
DENSITY (g/L)	44	46	22	9–96
HANDLE (min)	30	24	20	0–78
HAUL (min)	30	290	130	71–500
DAY	44	313	12.3	296–336
LKTEMP (°C)	44	17.7	2.5	14–22
Number in pen	44	289	106	102–521
TEMPDIF (°C)	44	2.3	1.5	0–5
TL (mm)	18	56.7	6.6	43–71
TNTEMP (°C)	44	15.7	2.7	9–19
VOL (L)	44	949	382	549–1,779

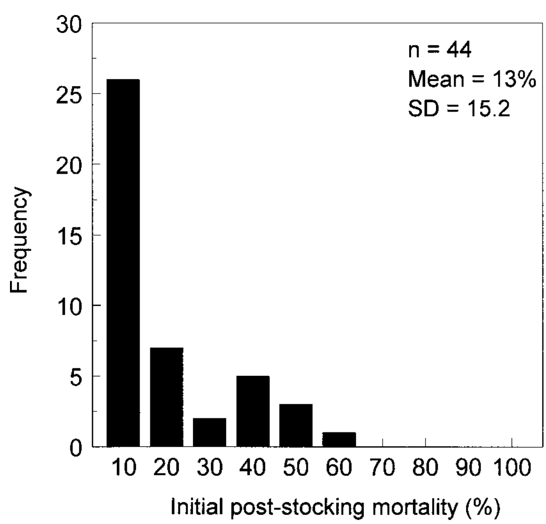

FIGURE 1.—Frequency distribution of initial post-stocking mortality estimated from net-pen trials for fingerling black-nosed crappies stocked into Tennessee reservoirs during fall 1997–1999.

TABLE 4.—Year-class contributions for black-nosed crappies marked with oxytetracycline, stocked into three Tennessee reservoirs, and subsequently sampled via electrofishing (EF), trap nets (TN), or rotenone (RO). The stocking contribution represents the percentage of all crappies within each designated age-class that displayed a mark. Mark longevity represents the interval between marking and recapture (see Table 2).

Lake	Cohort	Recapture gear	Age at contribution	Number of crappies		Contribution (%)	Longevity (weeks)
				Total	Marked		
Graham	1998	EF	1	0	0	0	
		TN	1	0	0	0	
Normandy	1997	RO	1	90	84	93	36
		EF	2	34	24	71	68
		RO	2	39	36	92	76
		EF	3	70	58	83	110
	1998	RO	1	154	131	85	32
		EF	2	61	21	34	66
Woods	1998	EF	1	110	26	24	48
		EF	2	163	18	11	70

amount of variability explained by the combination of these variables was low (R^2 = 0.15; df = 2, 43; P = 0.03).

Despite the existence of multicollinearity, which can mask the effects of individual variables, all variables (excluding VOL and DAY) were included in an additional multiple regression model to determine the level of variability in mortality data that was explained by all stocking variables. This model explained 53% of the variability in mortality values (R^2 = 0.53; df = 5, 25; P = 0.0062):

$$\begin{aligned}\text{MORTALITY} = &\\ &-49.3 - 3.76(\text{TEMPDIF}) + 0.90(\text{TL})\\ &+ 0.32(\text{DENSITY}) - 0.04(\text{HAUL})\\ &+ 1.71(\text{LKTEM}).\end{aligned}$$

On an individual basis, only TEMPDIF explained greater than 15% of the variability in the five-variable model (partial R^2 = 0.19; F = 5.51; df = 5, 25; P = 0.03).

Oxytetracycline Marking

Water temperatures at time of OTC marking ranged from 14°C to 21°C. Marking efficacy was high on all marking dates, ranging from 97% to 100%. Marks persisted well in all Normandy Reservoir cohorts; 99% (323 of 327) of recaptured black-nosed crappies known to be marked still retained highly visible marks 36–110 weeks after marking. All white crappie otoliths (N = 78) were correctly scored as unmarked during the duration of the study. Due to high marking efficacy and retention rates subsequent estimates of stocking contribution were not corrected for mark loss.

Stocking Contribution

Year-class contribution was variable among reservoirs, ranging from 0% to 93% (Table 4). Highest contributions occurred in Normandy Reservoir (34–93%). The majority (73%, 327 of 448) of crappies collected in all samples from Normandy Reservoir were stocked black-nosed crappies. Additionally, 40% (30 of 75) of all black crappies lacking a predorsal stripe were identified as stocked fish. Black-nosed crappies were stocked at a higher rate in 1998 (50/ha) than in 1997 (31/ha), but contribution from the 1998 cohort (Table 4) was lower at age 1 (χ^2 = 3.71, df = 1, P = 0.054) and age 2 (χ^2 = 11.45, df = 1, P = 0.001), probably as a result of increased natural black crappie recruitment in 1998. Age-2 contribution estimates from electrofishing were lower than age-1 estimates from rotenone samples (Table 4) for both the 1997 (χ^2 = 11.36, df = 1, P = 0.001) and 1998 Normandy cohorts (χ^2 = 54.08, df = 1, P = 0.001). Stocking contribution of the 1997 Normandy Reservoir cohort remained consistent from age 1 to age 2 within rotenone samples (χ^2 = 0.04, df = 1, P = 0.834) and from age 2 and age 3 in electrofishing samples (χ^2 = 2.07, df = 1, P = 0.151). The consistency of contribution estimates over time suggests that the survival of stocked black-nosed crappies was proportional to the survival of wild crappies.

Year-class contribution in Woods Reservoir was considered intermediate; stocked black-nosed crappies only represented 11–24% of the 1998 year-class at age 1 and age 2 (Table 4). Wild black (31%) and white crappies (42%) made up 73% (80 of 110) of the age-1 crappies collected from Woods Reservoir in the 1999 electrofishing sample. Only

17% (7 of 41) of the black crappies lacking a predorsal stripe exhibited OTC marks. Similarly, in the 2000 electrofishing sample, wild black (20%) and white crappies (66%) made up 86% of all age-2 crappies collected; only 13% (5 of 38) of black crappies lacking a predorsal stripe exhibited OTC marks. Contribution in electrofishing samples was not consistent from age 1 to age 2 ($\chi^2 = 7.70$, df $= 1$, $P = 0.006$). Based on May 2000 electrofishing samples, the contribution of black-nosed crappies stocked in 1998 was three times higher in Normandy Reservoir than in Woods Reservoir ($\chi^2 = 16.88$, df $= 1$, $P = 0.001$; Table 4), despite similar stocking rates (Table 2).

Contribution was considered negligible in Lake Graham, where no crappies were collected (Table 4). Trap nets and electrofishing were considered effective gears for sampling crappies in Lake Graham; hence, the lack of crappies indicated that crappie density in Lake Graham was low and that stocked fish did not survive well.

Stocking black-nosed crappies had a dramatic effect on the composition of crappies harvested by anglers in Center Hill Reservoir (Figure 2). Three years after stocking was initiated, black-nosed crappies made up over 50% of all harvested crappies observed in angler creels. In contrast, despite the fact that 1.2 million crappies had been stocked into Cherokee Reservoir between 1995 and 1999, black-nosed crappies represented no more than 12% of all harvested crappies observed in creel surveys (Figure 2). Similarly, black-nosed crappies made up no more than 6% of all crappies collected in annual TWRA fall trap-net samples during 1996–1998 (Sammons et al. 2000).

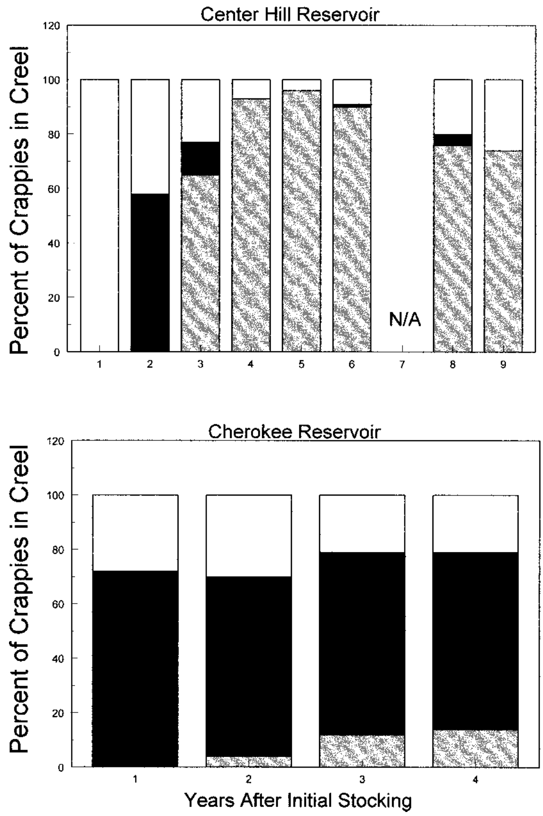

FIGURE 2.—Percentage of black-nosed (gray bars), black (solid bars), and white crappies (white bars) creeled in Center Hill and Cherokee reservoirs. Black-nosed crappies were first stocked in Center Hill Reservoir in 1990 and in Cherokee Reservoir in 1995.

Discussion

Few studies have analyzed the immediate survival of recently released, hatchery-reared fish (Parker 1986), and few estimates have been reported for crappies. Pitman and Gutreuter (1993) reported that three stockings of crappies in Texas resulted in 24-h survival rates between 98% and 100%. Conversely, Smeltzer and Flickinger (1991) reported high rates of handling mortality (80–100%) for crappies stocked during summer months in Colorado. The average initial poststocking mortality rate (13%) for crappie fingerlings stocked into Tennessee reservoirs was higher than rates reported by Pitman and Gutreuter (1993) and much lower than estimates reported by Smeltzer and Flickinger (1991). Relatively low initial poststocking mortality rates (≤15%) have also been reported for fry of walleye *Stizostedion vitreum* (Hoxmeier et al. 1999) and for fingerlings of largemouth bass *Micropterus salmoides* (J. Hoxmeier, Illinois Natural History Survey, unpublished data) and coppernose bluegill *Lepomis macrochirus purpurescens* (Pitman and Gutreuter 1993).

Nearly all of the variables we measured as potential predictor variables for explaining variability in initial mortality of stocked black-nosed crappies have been implicated as causative agents in regulating the survival of recently stocked fishes (Schreiner 1985; Mather et al. 1986; Pitman and Gutreuter 1993; Clapp et al. 1997). Regression analyses indicated that initial mortality of crappies stocked into Tennessee reservoirs was a complex process regulated by numerous variables, some of which were not measured and others that were unquantifiable. Conditions in hatchery ponds during draining and crappie removal (i.e., water quality, crappie density), as well as crappie condition, probably influenced initial survival. Hatchery protocols and environmental conditions in late fall were generally conducive to the high initial survival of crappies. The relationship between the survival of recently stocked crappies and eventual year-class contribution is unknown at this time; however, poor initial survival rates would obviously reduce stocking contribution. Hoxmeier et al. (1999) reported that in Illinois reservoirs, initial mortality rates greater than 20% produced relatively low fall electrofishing catches of age-0 walleyes stocked as fry.

Mortality of walleyes and saugers *S. canadense* marked with OTC-immersion have been reported as low (1–14%, Heidinger et al. 1987, 1996), and increases in mortality due to immersion marking with tetracycline antibiotics have frequently been negligible (Secor et al. 1991; Conover and Sheehan 1996; Peterson and Carline 1996). As in our evaluation, Conover and Sheehan (1996) reported that OTC-immersion did not significantly increase mortality of juvenile black crappies. Additionally, the survival of OTC-marked crappies in Tennessee was much higher than that of fingerling black crappies that were marked with coded wire tags and stocked into a Florida lake (Myers et al. 2000).

Long-term persistence of OTC marks, up to 5 years, has been reported for several species (Bilton 1986; Unkenholtz et al. 1997; Heidinger and Brooks 1998; Reinert et al. 1998). However, degradation of OTC marks has been shown to occur over time (Lorson and Mudrak 1987). Conover and Sheehan (1999) reported that marks persisted 31 weeks on 88% of otoliths collected from black crappies marked using the same OTC immersion protocol incorporated in our evaluation. Mark retention reported by Conover and Sheehan (1999) was confounded by the fact that marking efficacy and retention were estimated simultaneously at 31 weeks (Conover and Sheehan 1996, 1999); an earlier estimate of marking efficacy would have allowed researchers to determine whether the lack of marks on 12% of the OTC-treated fish was due to initial marking rates or to lack of mark persistence (i.e., fish were initially marked and the marks later deteriorated).

Estimates of mark retention should incorporate determination of marking efficacy before estimating retention to determine the percentage of fish retaining the mark during the designated period (Secor et al. 1991; Unkenholtz et al. 1997; Reinert et al. 1998). We estimated efficacy and retention simultaneously at 36 weeks for black-nosed crappies stocked into Normandy Reservoir in 1997; however, marking efficacy was high (97%) and longevity of marks for this cohort was later estimated at two different time intervals. Efficacy was estimated before longevity in all other trials. In several studies large percentages of fish have retained oxytetracycline marks over relatively long periods (Secor et al. 1991; Brooks et al. 1994; Unkenholtz et al. 1997).

Stocking contribution has been shown to vary across waters stocked in similar manners (Willis and Stephen 1987; Li et al. 1996; Hoxmeier et al. 1999) and across years within the same system (Fielder 1992; Elrod et al. 1993; Heidinger and Brooks 1998). Additionally, supplemental stockings of largemouth bass and walleyes have commonly been deemed unsuccessful (Laarman 1978; Loska 1982). Laarman (1978) reported that only 5.2% of 58 supplemental walleye stockings were considered relatively successful. Information concerning the success of stocking crappies into large impoundments is lacking. Myers et al. (2000) reported that stocked black crappies made up 4.8% of the age-1 crappies collected from a 65-ha Florida lake; however, high initial poststocking mortality probably reduced stocking contribution. Low estimates of year-class contribution (0–3.1%) were also reported for white crappies stocked into Lake Chicot, Arkansas (Racey 2001).

Contributions of stocked crappies in Normandy Reservoir were similar or higher than reported rates of year-class contributions for saugers stocked in the Illinois River (15–76%; Heidinger and Brooks 1998), walleyes stocked in Claytor Lake in Virginia (67%; Murphy et al. 1983), walleyes (17–100%; Lucchesi 2002) and yellow perch *Perca flavescens* (5–38%, Brown et al. 2000) stocked in South Dakota natural lakes, and largemouth bass stocked in small Oklahoma impoundments (72–76%; Boxrucker 1986). Based on these published estimates of stocking contribution, the age-1 contribution of stocked fish in Woods Reservoir was considered low. The relative failure of stockings in Cherokee Reservoir and Lake Graham indicate crappie stocking is not successful in all impoundments. Predation on stocked crappies by resident piscivorous fishes may explain the relatively low contribution of stocked crappies in Woods Reservoir and the failure of crappie stockings in Cherokee Reservoir and Lake Graham (Sammons et al. 2000); however, factors regulating crappie stocking success in Tennessee reservoirs are unknown at this time.

In Tennessee reservoirs where stocking has proven to be successful, stocking contribution will vary with fluctuations in natural year-class strength. Heidinger and Brooks (1998) reported that stocking contribution of saugers in the Illinois River was negatively related to levels of natural recruitment; contributions were highest in years when natural recruitment of saugers was low.

Additionally, contribution estimates for the same cohort of stocked crappies showed variability between gears and seasons. Rotenone samples yielded age-1 contribution estimates that were significantly higher than age-2 estimates obtained from spring electrofishing for both cohorts of crappies stocked into Normandy Reservoir, possibly due to the proximity of coves to stocking sites. Reduced manpower requirements allowed us to collect more samples with electrofishing than with rotenone, resulting in a more extensive distribution of sample sites within the reservoir. Although we did not specifically analyze dispersal patterns of stocked black-nosed crappies, we did observe a decline in the abundance of stocked crappies as distance of electrofishing sites from stocking locations increased. Stocking contribution of the 1998 cohort increased from fall to spring in Woods Reservoir electrofishing samples, suggesting that age-1 stocked crappies may not have fully recruited to fall electrofishing.

Management Implications

In most cases, initial poststocking mortality does not appear to be a major factor regulating the effectiveness of black crappie stocking in Tennessee reservoirs. However, further analyses of factors responsible for this mortality may help improve the stocking process. Additionally, stocked black-nosed crappies were generally smaller than wild age-0 black and white crappies collected from Tennessee reservoirs during the stocking period (Sammons et al. 2000). Predation of stocked crappies did occur in Tennessee reservoirs and could be high in systems with high densities of littoral zone predators (Sammons et al. 2000). Stocking period, crappie size at stocking, and predation rates following release all could affect stocking success and need to be further evaluated to determine optimal stocking conditions.

Due to the relatively high contributions of stocked crappies at ages 1 (both cohorts) and 2 in Normandy Reservoir, stocked crappies are expected to contribute to the fishery once the majority of stocked fish reach harvestable size (about age 3). The failure of black-nosed crappie stockings in some Tennessee reservoirs indicates that continued releases of hatchery-reared crappies into these systems are ill-advised; crappie production can be reduced or diverted to reservoirs where stocking has shown the potential to positively affect the crappie fishery. Reallocation of crappie production would allow larger numbers of crappies to be stocked into reservoirs where stocking has proven to be successful and may further augment the crappie fishery in these systems.

Sammons and Bettoli (1998) demonstrated that year-class strength of crappies in Normandy Reservoir could be indexed using larval fish sampling. The ability to predict year-class strength before stocking, coupled with knowledge concerning stocking efficacy, will allow managers to stock crappies when and where they are needed with confidence that such stockings will reduce adverse effects on crappie fisheries effected by weak or failed natural recruitment.

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