Stocking Contributions of Black Crappie Fingerlings in Lake Hickory, North Carolina

Kevin J. Hining, *North Carolina Wildlife Resources Commission, 1556 Big Flatts Church Rd., Fleetwood, NC 28626*

Kinnon B. Hodges, *North Carolina Wildlife Resources Commission, 179 Stone Bridge Rd., Mount Airy, NC 27030*

David L. Yow, *North Carolina Wildlife Resources Commission, 57 Hilltop Rd., Asheville, NC 28803*

Abstract: Lake Hickory is a 1660-ha impoundment in western North Carolina with a historically popular black crappie (*Pomoxis nigromaculatus*) fishery. Beginning in 2000, North Carolina Wildlife Resources Commission (NCWRC) trapnet-survey data suggested a decline in black crappie catch rates which was also associated with increased angler complaints. In an effort to improve the black crappie population, the NCWRC began an experimental stocking program in 2007. From 2007 to 2012, black crappie fingerlings were marked with oxytetracycline (OTC) and stocked annually into Lake Hickory. Annual assessments of initial poststocking survival of OTC-marked fish (79%–98%) and OTC mark efficacy (96%–100%) were high. Black crappie were collected using trapnets set in the fall during 2008–2012. All captured black crappie were aged, and otoliths from fish in the 2007–2011 year classes were examined for an OTC mark. Year-class contributions ranged from 0%–95%. As of the 2012 trapnet survey, approximately half (48%) of the black crappie collected with trapnets that were from the 2007 or later year classes bore an OTC mark. Continued stocking of black crappie fingerlings is recommended, along with routine trapnet surveys to verify contributions of stocked fish and overall improvements to the Lake Hickory black crappie population.

Key words: oxytetracylcine, mark efficacy, trapnets, poststocking survival

Journal of the Southeastern Association of Fish and Wildlife Agencies 3:11–16

Crappie (*Pomoxis* spp.) angling represents a significant portion of the recreational fishing in the inland waters of North Carolina (Linehan 2013) and surrounding region (U.S. Fish and Wildlife Service and U.S. Census Bureau 2011). However, crappie populations often exhibit erratic recruitment (Miller et al. 1990, Colvin 1991, Mitzner 1995), making them difficult to manage. In an attempt to counter recruitment issues, several southeastern states have initiated supplemental crappie stocking programs (Isermann et al. 2002, Anderson and Williams 2008, Diana et al. 2014, Wright et al. 2014).

Supplemental stocking has been used for a variety of sportfish (Pitman and Gutreuter 1993, Welcomme and Bartley 1998, Heidinger 1999, Myers et al. 2000, Racey and Lochmann 2002, Diana et al. 2014). The effectiveness of these stockings are often unknown as a result of limited evaluation (Cowx 1998, Quiros 1998, Racey and Lochmann 2002), or unpredictable due to varied stocking success (Myers et al. 2000, Isermann et al. 2002, Racey and Lochmann 2002). While some supplemental stocking programs are successful (Isermann et al. 2002), others have shown marginal contributions (Racey and Lochmann 2002, Besler 2004, Anderson and Williams 2008, Wright et al. 2014), especially during years of high natural recruitment (Heidinger and Brooks 1998, Isermann et al. 2002). Some stocking programs have been too successful, suppressing overall fish abundance (Li et al. 1996). The wide range of results coupled with the manpower, hatchery, and financial constraints that stocking programs often involve, necessitates the need for thoughtful evaluation.

Success of any stocking program depends on a variety of factors, including initial survival of stocked fish, year-class contribution, and improvements to the overall abundance of the fishable population. Evaluating these variables involves monitoring immediate survival, as well as survival of stocked fish over time (Pitman and Gutreuter 1993, Isermann et al. 2002, Racey and Lochmann 2002). Assessing post-stocking survival requires efficient capture of stock-sized and larger fish and distinguishable characteristics to identify stocked fish (Murphy and Kelso 1986). Previous work has demonstrated that mass-marking with oxytetracycline (OTC) by immersion is an effective method for black crappie (*Pomoxis nigromaculatus*), and that a high percentage of fish retain the mark later in life with no adverse effects on survival, growth, and condition (Conover and Sheehan 1999, Isermann et al. 2002).

Lake Hickory is a 1660-ha, mesotrophic impoundment in western North Carolina with a historically popular black crappie fishery. Declining catch rates of black crappie in North Carolina Wildlife Resources Commission (NCWRC) trapnet surveys were observed following a peak at 8.3 fish net night^{-1} in 1999, which dwindled to 0.4 fish net night^{-1} by 2006 (Hining 2010). Concurrently, angler complaints regarding poor catch rates of black crappie became more frequent. Reasons behind the decline of the black crappie population in Lake Hickory are unknown, and cursory investigations into possible changes in primary productivity, hydrology, spawning habitat, and angler harvest have provided little guidance (Hining 2007, 2010). However, between the late 1990s and early 2000s alewife (*Alosa pseudoharengus*) and white perch (*Morone americana*) were introduced into Lake Hickory. These unauthorized introductions could have affected black crappie recruitment, since both species are known to impact resident sportfish by competing for food with various life stages and preying on eggs and larvae (Kohler and Ney 1980, Madenjian et al. 2000).

Several studies have found that crappie year-class strength was determined early in life, even before spawning began (Maceina and Stimpert 1998, Sammons and Bettoli 2000, Maceina 2003). Furthermore, Sammons and Bettoli (1998) found that abundance of crappie larvae was a strong indicator of future year-class strength of crappies in a Tennessee reservoir, indicating that larvae production was a major determinant of crappie recruitment. If recruitment impacts are occurring early in life, it may be possible to circumvent the issue(s) and improve abundance through the stocking of black crappie fingerlings (Isermann et al. 2002).

Therefore, to address the decline in the black crappie fishery, the NCWRC began supplemental stocking OTC-marked black crappie into Lake Hickory. If stocked black crappie recruit successfully and contribute to the overall population, it would suggest that recruitment is being limited at the early life stages and that stocking may be an option for improving the abundance and angler catch rates of black crappie in Lake Hickory. Thus, the primary goal of this study was to evaluate the effectiveness of stocking in supplementing Lake Hickory's black crappie population. Objectives included 1) evaluate 24-h poststocking survival of black crappie, 2) assess mark efficacy for black crappie using OTC, and 3) estimate stocking contribution of stocked black crappie fingerlings.

Methods

Black Crappie Stocking, Initial Poststocking Survival, and Mark Efficacy

Black crappie were reared in ponds at three NCWRC hatcheries annually from 2007 to 2012. Based on the reported range of stocking rates from other attempts to supplement crappie populations (Isermann et al. 2002, Racey and Lochmann 2002), efforts were made to produce a minimum of 80,000 fingerlings annually for a minimum stocking density of 48 fish ha^{-1}. During late summer (August–September), fingerling black crappie were collected with seines from partially drained ponds. Subsamples of black crappie were counted and weighed to estimate total number harvested, transferred indoors to 1064-L tanks, and immersed in a solution of 500 mg L^{-1} oxytetracycline (OTC) and approximately 300 mg L^{-1} sodium phosphate dibasic buffer for six hours (Isermann et al. 2002). Approximately 100 black crappie were retained at the hatchery for mark efficacy, and all other fish were transported to Lake Hickory by stocking truck. Once at the lake, the hauling tanks were tempered and all fish were loaded into a boat-mounted stocking tank. Fish were distributed by boat into open water throughout the main lake channel. A sample of at least 150 fish was returned to the boat ramp after the stocking was completed and used for initial (24-h) poststocking survival estimates.

To estimate 24-h poststocking survival, fish were placed into a vented, 1-m diameter by 0.5-m deep hard plastic pen set on the bottom of the lake, at approximately 2 m deep. The pen was collected 24 h later, and the number of living and dead black crappie was recorded. Initial poststocking survival was estimated as the total number of live fish divided by the total number of fish (alive and dead) and multiplied by 100. Finally, approximately 30 randomly-selected fish were measured to determine mean total length of stocked black crappie.

Mark efficacy was determined each year from black crappie fingerlings retained at the hatchery and fed for 30 days following the OTC immersion (Isermann et al. 2002). Following the 30-day period, fish were sacrificed and sagittal otoliths were removed from a random sample of 25–100 fish. One whole otolith from each fingerling black crappie was mounted on a microscope slide using cyanoacrylate super glue and viewed by a single reader under a Nikon Eclipse E400 compound microscope equipped with a transmitted epiflourescent light source (Secor et al. 1991). If an OTC mark was not visible, the otolith was wet ground with 600-grit wet-dry sandpaper and viewed again (Isermann et al. 1999). The process was repeated until an OTC mark was observed, or the focus was reached.

Poststocking Contribution and Overall Effectiveness of Stocking

Black crappie were sampled from Lake Hickory with trapnets in fall from 2008 to 2012. Ten trapnets, each having 25-mm bar mesh, were set at fixed sites perpendicular to the shoreline. Nets were set on Monday and checked after 48 h and again after another 48 h, resulting in a total of 40-net nights of effort each year. Total length (mm) and weight (g) were obtained for all black crappie, and sagittal otoliths were removed for aging. All otoliths were read independently by two readers, and discrepancies in annuli counts between readers were rectified by a joint reading.

Otoliths from all black crappie within year classes that could potentially contain stocked fish were examined for an OTC mark. In addition, otoliths from white crappie (*P. annularis*; $n = 47$) were arranged as a blind test, to serve as a control (Isermann et al. 1999, Logsdon et al 2009). One whole otolith from each fish was glued to a glass slide using cyanoacrylate super glue. A Buehler Isomet low speed diamond wheel saw was used to cut two 0.5-mm transverse sections through the dorsoventral plane (Allen et al. 2003). Sections were permanently mounted onto glass microscope slides using Shandon synthetic mountant (Thermo Scientific, Waltham, Massachusetts) and examined for an OTC mark as described previously. Fish with an OTC mark were considered to be stocked fish. Year-class contribution was defined as the percentage of stocked fish in each year-class.

Results

Black Crappie Stocking, Initial Poststocking Survival, and Mark Efficacy

The number of black crappie fingerlings stocked each year ranged from 22,000–105,000, and only exceeded the target stocking number of 80,000 in 2008 (Table 1). In contrast to the variation observed in the numbers stocked, the mean total length of fingerling black crappie at time of stocking ranged only from 50–66 mm during the six years. Mortality during marking and immediate post-marking was not quantified, but appeared to be minimal during all years. Poststocking survival (24-h) of OTC marked black crappie was high 4 of 6 years (≥96%), but declined to 79% in 2009 and 87% in 2010. Marking efficacy was high each year, ranging from 96% to 100% (Table 2). As a result of high mark efficacy and limitations on staff time, the number of fingerlings used to determine mark efficacy was reduced to 50 in 2008 and 2009 and to 25 from 2010 to 2012. Only 3 of 275 marked fingerlings checked for an OTC mark during the study were scored as unmarked, and in all three cases, aggressive sanding of the otolith may have been to blame for the inability to see the mark. As a result of this potential reader error coupled with high overall mark efficacy, estimates of stocking contribution were not corrected for mark loss.

Table 1. Stocking date, number (*n*) and rate, hauling distance, mean total length (TL), and 24-h survival data for black crappie stocked into Lake Hickory, North Carolina, 2007–2012.

Stocking Date	No. (1000s)	Rate (*n*/ha)	Hauling distance (km)	Mean TL (mm)	Number fish in cage	24-h survival (%)
26 September 2007	22	13	72	52	566	98
18 September 2008	105	63	72	58	285	98
16 September 2009	45	27	441	66	677	79
23 September 2010	71	43	441	57	149	87
22 September 2011	70	42	72	51	270	98
8 August 2012	48	29	72	50	626	96

Table 2. Mark retention of age-0 black crappie treated with oxytetracycline and held for 30 days poststocking, 2007–2012.

Year	Number	Percent marked
2007	100	99
2008	50	98
2009	50	100
2010	25	100
2011	25	96
2012	25	100

Table 3. Year-class contributions for black crappie marked with oxytetracycline, stocked into Lake Hickory, North Carolina, and subsequently sampled with trapnets. The year-class contribution represents the percentage of all black crappie within each designated age-class that displayed a mark. Mark longevity represents the interval between marking and recapture.

Cohort	Sample year	Age at contribution	Number of black crappie		Year-class contribution (%)	Mark longevity (months)
			Total	Stocked		
2007	2008	1	9	2	22	14
	2009	2	11	3	27	25
	2010	3	16	8	50	38
	2011	4	2	0	0	50
	2012	5	2	1	50	61
2008	2009	1	20	19	95	13
	2010	2	44	40	91	26
	2011	3	13	12	92	38
	2012	4	10	6	60	49
2009	2010	1	10	1	10	14
	2011	2	38	7	18	26
	2012	3	54	10	19	37
2010	2011	1	10	2	20	14
	2012	2	66	35	53	25
2011	2012	1	5	3	60	13

Poststocking Contribution and Overall Effectiveness of Stocking

The OTC immersion process used in this study resulted in clear, discernable marks that were present in fish up to age 5. Furthermore, blind reading of untreated white crappie otoliths were all correctly scored as unmarked, and provided a quality control measure. Year-class contribution was variable among sample years, ranging from 0–95% (Table 3). Stocked fish were found in every cohort/sample year combination except for age-4 fish in 2011, which may have been a result of small sample size ($n = 2$). Percent contributions of stocked black crappie were also low for age-1 fish in 2008 (22%) and 2011 (20%), and for the 2009 cohort (10%–19% depending on sample year). However, the mean year-class contribution for the remaining nine year-classes was 64%, with five of the nine ≥60%. From 2008 to 2012, approximately half (48%) of the black crappie collected from year classes when stocking occurred were stocked, and 33% of all black crappie collected were stocked.

Discussion

Black Crappie Stocking, Initial Poststocking Survival, and Mark Efficacy

The wide range of observed stocking rates were due to a variety of factors, including brood stock health, fingerling escapement and mortality, and restricted pond space. A review of other supplemental crappie stocking studies revealed a similar wide range of stocking rates (Isermann et al. 2002, Racey and Lochmann 2002, Anderson and Williams 2008, Wright et al. 2015). Like most agencies, space for rearing fish is competitive at NCWRC hatcheries as a result of multiple stocking programs coupled with finite hatchery facilities. However, future expansion of NCWRC hatcheries are planned, and will hopefully allow for increased production.

Length range of stocked black crappie fingerlings at Lake Hickory was less variable than reported in similar studies involving stocked crappie (Tennessee reservoirs: 43–71 mm, Isermann et al. 2002; Lake Chicot, Arkansas: 56–128 mm, Racey and Lochmann 2002). While larger fingerlings often exhibit higher survival rates (Hume and Parkinson 1988, Heidinger 1999), neither Isermann et al (2002) or Racey and Lochmann (2002) observed a definitive link between mean total length of stocked black crappie fingerlings and year-class contribution. As a result, the low variability in mean total lengths observed is believed to have had a limited role in year-class contribution during this study.

Isermann et al. (2002) reported that initial mortality of crappie stocked into Tennessee reservoirs was a complex process regulated by several variables, including some that were impossible to quantify. While the factors responsible for the variation observed in 24-h survival rates observed in our study were unknown, the hauling distance during the years of lower survival was much longer than in other years. Furthermore, black crappie stocked into Lake Hickory during 2013 were also hauled for an extended distance (349 km) and 24-h survival (82%) was also relatively low (NCWRC unpublished data). Though speculative based on a limited number of trials and few recorded variables, the data suggest that longer hauling times may result in poorer survival. Regardless, survival observed during this study was similar to other supplemental stocking studies involving OTC-marked crappie (Isermann et al 2002, Racey and Lochmann 2002).

Mark efficacy of black crappie was high on all marking dates, suggesting that OTC immersion was highly effective for identifying stocked crappie. Similar studies involving crappie reported high mark efficacy of fingerlings from OTC immersion, ranging from 97%–100% (Isermann 1999, Isermann et al. 2002, Racey and Lochmann 2002, Wright et al. 2015). However, mark detection errors observed in other studies suggest the need for controls during future mark efficacy testing (Logsdon et al. 2009).

Poststocking Contribution and Overall Effectiveness of Stocking

Disparity in stocking contribution across years has been observed in other waters for a variety of species (Fielder 1992, Elrod et al. 1993, Heidinger and Brooks 1998), including black crappie (Isermann et al. 2002). Common issues that might result in varying contributions of stocked fish from year to year on the same water include handling mortality and time of year fish are stocked (Isermann et al. 2002), stocking location in relation to potential predators (Elrod 1997), and size of stocked fish (Shireman et al 1978). However, small sample sizes may also result in poor or erroneous estimates of year-class contributions, because larger samples generally estimate characteristics of the population more accurately (Brown and Austen 1996). In all but the 2008 cohort, year-class contributions of age-2 fish were higher than those obtained for age 1. This is likely a result of small sample size for age-1 fish, which could be a result of excluding younger individuals as a result of gear bias, as black crappie in Lake Hickory do not fully recruit to trapnets until age 2 (Hining 2007, 2010). Similar issues with small sample sizes may occur for older black crappie as well, given reported bias of trapnets towards smaller and young crappies in southeastern U.S. impoundments (Maceina and Stimpert 1998, Sammons et al. 2002). Also, their popularity as a food fish and associated high exploitation (Reed and Davies 1991, Allen and Miranda 1995) could also limit numbers of older black crappie for stocking contribution estimation.

Temporal degradation of OTC marks may also confound accurate year-class contribution estimates. OTC marks have been shown to persist for several years for some species (Secor et al. 1991, Brooks et al. 1994, Logsdon et al. 2009), but have been reported to fade over time and become harder to find as otolith size and thickness increases (Lorson and Mudrak 1987). Isermann et al. (2002) evaluated the persistence of OTC marks in black crappie up to 110 weeks, but little work has been done over longer intervals. While marks were observed in fish up to age 5 in this study (> 250 weeks), sample sizes of older fish were small, and high variation in stocking contribution between age-3 and age-4 fish from the 2008 cohort and between age-4 and age-5 fish in the 2007 cohort could also have been caused by degrading OTC marks. Thus, future surveys designed to examine year-class contribution of stocked black crappie should focus on age-2 fish. This will also be more efficient and reduce manpower needs, since only otoliths from age-2 fish will need to be sectioned, mounted, and checked for OTC marks.

Isermann et al. (2002) suggested that naturally produced black crappie have an advantage over their stocked conspecifics and are therefore unlikely to be replaced by stocked individuals. Stocked black crappie in Lake Hickory also appeared to be additive to the existing fishery, based on the fact that all cohorts consisted of both stocked and wild fish during this study. From 2009 to 2012, trapnet catch rates of black crappie in Lake Hickory were 29%–41% higher with stocked fish than rates calculated using only wild fish. Furthermore, while angler creel data was not collected during this study, frequent staff communication with anglers and local fishing guides suggested the black crappie fishery has improved since stockings were initiated in 2007.

Stocked black crappie contributed to multiple year classes in Lake Hickory, and 33% of all black crappie collected from 2008 to 2012 were stocked. Mass-marking of black crappie with OTC appears to be a valuable tool for determining the success of previous stockings. Continued stocking of OTC-marked fingerlings into Lake Hickory should continue, along with routine monitoring of the black crappie fishery and determination of the contribution of stocked fish. Future evaluations of stocked black crappie at Lake Hickory should consider monitoring fingerling survival during and immediately following OTC marking, a quality control measure for OTC mark efficacy testing, and sampling the recreational creel to determine the contribution of stocked black crappie.

Acknowledgments

This project was funded by NCWRC, with assistance from the U.S. Fish and Wildlife Service Sport Fish Restoration Program. We would like to thank staff at the NCWRC Marion, Tablerock, and Watha State Fish Hatcheries for their help collecting and spawning adult black crappie, as well as rearing, marking, and stocking black crappie fingerings.

Literature Cited

Allen, M. S. and L. E. Miranda. 1995. An evaluation of the value of harvest restrictions in managing crappie fisheries. North American Journal of Fisheries Management 15:766–772.

———, K. I. Tugend, and M. J. Mann. 2003. Largemouth bass abundance and angler catch rates following a habitat enhancement project at Lake Kissimmee, Florida. North American Journal of Fisheries Management 23:845–855.

Anderson, M. and J. Williams. 2008. Evaluation of supplemental black crappie stocking programs at Laurel River Lake, Kentucky. Kentucky Department of Fish and Wildlife, Frankfort.

Besler, D. A. 2004. Contribution of stocked fingerling Walleyes in Lake James. North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Raleigh.

Brooks, R. C., R. C. Heidenger, and C. C. Kohler. 1994. Mass-marking otoliths of larval and juvenile walleyes by immersion in oxytetracycline, calcein, or calcein blue. North American Journal of Fisheries Management 14:143–150.

Brown, M. L. and D. J. Austen. 1996. Data management and statistical techniques. Pages 17–62 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Conover G. C. and R. J. Sheehan. 1999. Survival, growth, and mark persistence in juvenile black crappies marked with fin clips, freeze brands, or oxytetracycline. North American Journal of Fisheries Management 19:824–827.

Colvin, M. A. 1991. Population characteristics and angler harvest of white crappies in four large Missouri reservoirs. North American Journal of Fisheries Management 11:572–584.

Cowx, I. G. 1998. An appraisal of stocking strategies in the light of developing country constraints. FAO Fisheries Technical Paper 372:119–132.

Diana, M. J., M. A. Nannini, J. P. Gring, J. A. Garavaglia, and D. H. Wahl. 2014. Surveys and investigations for sportfish management in lakes and rivers in Illinois. Illinois Natural History Survey, University of Illinois.

Elrod, J. H. 1997. Survival of hatchery-reared lake trout stocked near shore and off shore in Lake Ontario. North American Journal of Fisheries Management 17:779–783.

———, C. P. Schneider, and D. E. Ostergaard. 1993. Survival of lake trout stocked into U.S. waters of Lake Ontario. North American Journal of Fisheries Management 13:775–781.

Fielder, D. G. 1992. Evaluation of stocking walleye fry and fingerlings and factors affecting their success in Lower Lake Oahe, South Dakota. North American Journal of Fisheries Management 12:336–345.

Heidinger, R. C. 1999. Stocking for sport fisheries enhancement. Pages 375–401 *in* C. C. Kokler and W. A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

——— and R. C. Brooks. 1998. Relative survival and contribution of saugers stocked into the Peoria Pool of the Illinois River, 1990–1995. North American Journal of Fisheries Management 18:374–382.

Hining, K. J. 2007. Characteristics of the black crappie population in Lake Hickory, 2003–2005. North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Raleigh.

———. 2010. Characteristics of the crappie populations in Lake Hickory, 2006–2009. North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Raleigh.

Hume, J. M. B. and E. A. Parkinson. 1988. Effects of size at and time of release on survival and growth of steelhead fry stocked in streams. North American Journal of Fisheries Management 8:50–57.

Isermann, D. A., P. W. Bettoli, and S. M. Sammons. 1999. Efficacy of identifying stocked crappies in a Tennessee reservoir using oxytetracycline marking. North American Journal of Fisheries Management 19:1122–1123.

———, ———, ———, and T. N. Churchill. 2002. Initial poststocking mortality, oxytetracycline marking, and year-class contribution of black-nosed crappies stocked into Tennessee Reservoirs. North American Journal of Fisheries Management 22:1399–1408.

Kohler, C. C. and J. J. Ney. 1980. Piscivory in a land-locked alewife (*Alosa pseudoharengus*) population. Canadian Journal of Fisheries and Aquatic Sciences 7:1314–1317.

Li, J., Y. Cohen, D. H. Schupp, and I. R. Adelman. 1996. Effects of walleye stocking on year-class strength. North American Journal of Fisheries Management 16:840–850.

Linehan, K. J. 2013. North Carolina angler opinion survey. North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Raleigh.

Logsdon, D. E., L. M. Miller, and C. S. Anderson. 2009. Evaluation of long-term retention and detection of oxytetracycline marks in walleye otoliths using genetic methodology. Transaction of the American Fisheries Society 138:872–887.

Lorson, R. D. and V. A. Mudrak. 1987. Use of tetracycline to mark otoliths of American shad fry. North American Journal of Fisheries Management 7:453–455.

Maceina, M.J. 2003. Verification of the influence of hydrologic factors on crappie recruitment in Alabama reservoirs. North American Journal of Fisheries Management 23:470—480.

——— and M. S. Stimpert. 1998. Relations between reservoir hydrology and crappie recruitment in Alabama. North American Journal of Fisheries Management 18:104—113.

Madenjian, C. P., R. L. Knight, M. T. Bur, and J. L. Forney. 2000. Reduction in recruitment of white bass in Lake Erie after invasion of white perch. Transactions of the American Fisheries Society 129:1340–1353.

Miller, S. J., D. D. Fox, L. A. Bull, and T. D. McCall. 1990. Population dynamics of black crappie in lake Okeechobee, Florida, following suspension of commercial harvest. North American Journal of Fisheries Management 10:98—105.

Mitzner, L. R. 1995. Effect of environmental factors and harvest regulations upon the crappie sportfishery at Rathbun Lake. Iowa Department of Natural Resources, Technical Bulletin 5, Des Moines.

Murphy, B. R. and W. E. Kelso. 1986. Strategies for evaluating fresh-water stocking programs: past practices and future needs. Pages 303–314 *in* R. H. Stroud, editor. Fish Culture in Fisheries Management. American Fisheries Society, Fish Culture Section and Fisheries Management Section, Bethesda, Maryland.

Myers, R. A., M. S. Allen, and D. E. Colle. 2000. Survival of fingerling black crappies tagged with microwire tags stocked in a Florida lake. North American Journal of Fisheries Management 20:534–537.

Pitman, V. M, and S. Gutreuter. 1993. Initial poststocking survival of hatchery-reared fishes. North American Journal of Fisheries Management 13:151–159.

Quiros, R. 1998. Reservoir stocking in Latin America, an evaluation. FAO Fisheries Technical Paper 374:91–117.

Racey C. L. and S. E. Lochmann. 2002. Year-class contribution of white crappie stocked into Lake Chicot, Arkansas. North American Journal of Fisheries Management 22:1409–1415.

Reed, J. R. and W. D. Davies. 1991. Population dynamics of black crappies and white crappies in Weiss Reservoir, Alabama: implications for the implementation of harvest restrictions. North American Journal of Fisheries Management 11:598–603.

Sammons, S. M. and P. W. Bettoli. 1998. Larval sampling as a fisheries management tool: early detection of year-class strength. North American Journal of Fisheries Management 18:137–143.

——— and ———. 2000. Population dynamics of a reservoir sport fish community in response to hydrology. North American Journal of Fisheries Management 20:791—800.

———, D. A. Isermann, and P. W. Bettoli. 2002. Variation in population characteristics and gear selection between black and white crappie in Tennessee reservoirs: potential effects on management decisions. North American Journal of Fisheries Management 22:863—869.

Secor, D. H., M. G. White, and J. M. Dean. 1991. Immersion marking of larval and juvenile hatchery-produced striped bass with oxytetracycline. Transactions of the American Fisheries Society 120:261–266.

Shireman, J. V., D. E. Colle, and R. W. Rottman. 1978. Size limits to predation on grass carp by largemouth bass. Transactions of the American Fisheries Society 107:213–215.

Welcomme, R. L. and D. M. Bartley. 1998. An evaluation of present technologies for the enhancement of fisheries. FAO Fisheries Technical Paper 374:1–35.

Wright, L. D., J. R. Jackson, S. E. Lochmann. 2014. An evaluation of crappie supplemental stocking in Arkansas impoundments. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:109—113.

U.S. Fish and Wildlife Service, and U.S. Census Bureau. 2011. 2011 National survey of fishing, hunting, and wildlife-associated recreation. U.S. Government Printing Office, Washington, D.C.