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Evaluation of a Supplemental Stocking Program to Improve the Largemouth Bass Fishery in the Markland and Meldahl Pools of the Ohio River

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Abstract

Supplemental stocking of largemouth bass *Micropterus salmoides* has often resulted in limited success in large systems. This study evaluated the effects of stocking 2.0 in largemouth bass fingerlings in embayments in the Markland and Meldahl pools of the Ohio River. Stocking density varied from 0 fish/acre in control embayments to 50 – 130 fish/acre in stocked embayments. Oxytetracycline marks on otoliths were used to distinguish between stocked and natural largemouth bass. Composition of stocked fish accounted for 47.7% of largemouth bass in the Markland Pool and 39.1% of largemouth bass in the Meldahl Pool collected each spring. Marked fish accounted for at least 38.6% of YOY largemouth bass examined in any given year in the Markland Pool, and on average accounted for 56.0% of the sample. Marked fish accounted for at least 45.3% of YOY largemouth bass examined in any given year in the Meldahl Pool, and on average accounted for 58.2% of the sample.

Post stocking fall CPUE of YOY largemouth bass in both the Markland (P=0.04) and Meldahl (P<0.01) pools were significantly higher than prestocking catch rates. Post stocking spring CPUE of Age-1 largemouth bass was significantly higher than prestocking catch rates in the Markland Pool (P=0.03), but the Meldahl Pool (P=0.12) showed no significant changes in catch rates. Catch rates of largemouth bass entering the fishery (statewide 12.0 in minimum size limit) significantly increased in both the spring (P=0.03) and fall (P=0.03) in the Markland Pool after stockings occurred, but remained indifferent in both the spring (P=0.74) and fall (P=0.97) in the Meldahl Pool.

Relative weight of largemouth bass in the Markland (P=0.20) and Meldahl (P=0.23) pools was not affected by stocking. Survival of natural YOY largemouth bass was also not affected by stocking in either the Markland (P=0.10) or Meldahl (P=0.11) pools. Growth rates of natural and stocked YOY largemouth bass were not significantly different in the Markland Pool (P=0.31), but stocked fish grew significantly faster in the Meldahl Pool (P<0.01).

Environmental factors such as discharge were analyzed and regressed against fall CPUE of natural YOY largemouth bass to determine if the effect on natural year class production in both the Markland and Meldahl pools. Minimum April – June discharge was the only environmental factors that had any significant correlation with strong natural year class production (P=0.05).

Introduction

Black bass *Micropterus salmoides* are among the most popular sport fishes pursued by recreational anglers across the United States (USFW and USCB 2011). Because of this popularity and rising fishing pressure, efforts on understanding the ecology and management of black bass have increased. Black bass make up an important part of the sport fishery in Kentucky. Hale et al. (1992) found that 51.1% of anglers questioned in a statewide survey fished regularly for black bass, and that 80.0% of anglers considered black bass one of the top three species to fish for. Black bass are traditionally thought of as lacustrine species, but nearly half of Kentucky anglers fished for black bass in the state's large rivers (Hale et al. 1992).

Angler concerns over the decline in largemouth bass in the Ohio River became apparent in 1997. Research was initiated to document largemouth bass populations in specific pools of the Ohio River in an effort to identify causes for these declines. The Ohio River Fish Management Team, an assemblage of Fisheries administrators and biologists along the Ohio River devised a work plan to study black bass populations along the length of the river. Survey results indicated that Ohio River largemouth bass abundance was low but growth rates were fast (Xenakis 2005). Largemouth bass reproduction was found to be negatively influenced by a number of variables including water levels, limited spawning habitat, and extreme siltation in spawning areas. Largemouth bass year-class production in the river appeared to be primarily impacted by habitat degradation and unstable water levels.

A study designed to supplement black bass spawning habitat in the Ohio River was initiated in 2004 with artificial spawning structures and habitat placed in impacted embayments in the Meldahl Pool of the Ohio River (Herrala 2013). Black bass have been observed utilizing both structures; however, the effort needed to significantly influence black bass reproduction on a pool wide basis through these means appears immense. A second possible way to increase year-class production in the river would be to renovate black bass spawning areas (embayments), but this method would be costly and would require expensive sediment removal and solutions in the drainage basin of each embayment in order to stop siltation once the renovation was complete.

Stocking hatchery-reared largemouth bass, a third possible solution, may be a more feasible method of enhancing black bass populations. Stocking has been utilized in the past to enhance black bass populations. Management agencies have stocked bass in an effort to populate new water bodies, supplement existing populations, and counter increased fishing pressure (Buynak and Mitchell 1999). Several studies have indicated that bass stockings contribute very little to black bass fisheries (Loska 1982, Boxrucker 1986). However, Copeland and Noble (1994) found stocking to be effective when bass populations were lacking sufficient nursery habitat and when recruitment was low. Long-term stocking has been shown to increase population abundance and improve black bass fisheries (Buynak and Mitchell 1999).

Most stocking studies have been conducted in impounded bodies of water and not in an open regulated river system like the Ohio River. Limited suitable habitat and emigration from stocking areas in riverine systems can be a concern. Janney (2001) stocked advanced fingerling largemouth bass into embayments of the Ohio River but found that mortality and emigration of these fish negated the benefits of stocking in those embayments. Others have found largemouth bass in large river ecosystems prefer off-channel habitats as both adult and sub-adult largemouth bass have been shown to utilize these backwater areas in greater proportion than their availability (Nack et al. 1993, Freund and Hartman 2005, Wallace and Hartman 2006). Other habitats such as main channel borders and tributaries may be used as supplemental habitat types or travel corridors during certain portions of the year (Nack et al. 1993, Janney 2001, Freund and Hartman 2005).

Supplemental stocking in large riverine systems has been shown to benefit largemouth bass population levels; however, because these stockings are complex, the exact contribution of these fish depends upon natural production, carrying capacity, and the relative survival of stocked and naturally produced fish (Heitman et al. 2006). Heitman et al. (2006) stocked 2.0 in fingerling largemouth bass directly into the Arkansas River to counter poor recruitment. They found that stocked fish did contribute to year-class strength at age-0 and age-1. Contributions of stocked young-of-the-year (YOY) largemouth bass in the fall ranged between 15.0 and 20.0% of age-0 fish sampled. By the following spring, stocked largemouth bass made up 9.0 to 13.0% of the age-1 year-class.

Stocking appears to be the next logical step in largemouth bass management options for the Ohio River. Supplemental stocking may be a means to enhance year-class strength of largemouth bass in the embayments of the Ohio River. This would in turn result in improvement in the largemouth bass fishery, which may result in increased angler satisfaction. The objectives of this study were to: 1) determine if stocking 2.0 in largemouth bass fingerlings could significantly increase catch rate of age-0 fish, catch rate of age-1 fish the following spring, and catch rate of fish entering the fishery (12.0 in statewide minimum size limit), 2) compare growth and catch rates of stocked and natural largemouth bass, and 3) determine factors that may be responsible for good year class survival of largemouth bass in the Ohio River.

Study Area

The Ohio River extends along the entire 664-mile northern border of Kentucky, and drains 39,210 mi^2 of the state. The Kentucky portion of the Ohio River is comprised of 8 high-lift dams and 2 wicket dams that form a series of pools and tailwaters along the river. The Markland Pool runs from Ohio River Mile (ORM) 436 to 531 (95 mi). Up to 16 embayments were stocked throughout the Markland Pool in both Kentucky and Indiana waters. Craig's Creek, Big Bone Creek, Paint Lick Creek, Gunpowder Creek, Woolper Creek, and the Licking River were sampled from 2004 – 2010, and Steele's Creek replaced the Licking River for annual sampling from 2011 – 2014 due to concerns over water quality. The Meldahl Pool runs from ORM 341 to ORM 436 (95 mi). Six embayments in the Meldahl Pool were sampled. Big Snag Creek, Big Locust Creek, Big Turtle Creek, and Bracken Creek were sampled from 2003 – 2014 with Lee's Creek and Lawrence Creek being added once stocking began in the Meldahl Pool in 2011.

Methods

Stocking

Largemouth bass fingerlings were spawned and reared to 2.0 in at Minor Clark Fish Hatchery in Morehead, KY. Largemouth bass were stocked into select embayments in the Markland Pool from 2007 – 2014 and in the Meldahl Pool from 2011 – 2014 at various stocking rates. Stocking rates were augmented in certain embayments throughout the study to determine what stocking rate produced the best results.

Sampling

Nocturnal, pulsed DC electrofishing was used to monitor largemouth bass populations in the spring and fall of each year from 2004 – 2014 in the Markland Pool and 2003 – 2014 in the Meldahl Pool when water temperatures were 60.0 - 70.0°F. Up to six 10-minute transects were made in each of the study embayments. During spring sampling all largemouth bass collected were measured (nearest 0.1 in), and otoliths were removed from a subsample of all fish collected. During fall sampling all largemouth bass collected were measured (nearest 0.1 in), weighed (nearest 0.01 lbs), and otoliths were removed from a subsample of fish through the 11.0 in class (age-0 fish).

Age structure and stocked fish contribution

Fingerling largemouth bass were marked with oxytetracycline (OTC) at Minor Clark Fish Hatchery prior to stocking. Fish were immersed in a 600 parts per million concentration buffered with sodium phosphate dibasic solution for approximately 5 hours. Fish were then removed from the solution to recover and hauled to stocking sites the next day. Otoliths were removed during spring and fall sampling to estimate age structure and checked for OTC marks to estimate the contribution of stocked fish to the population.

Data analysis

All sampling data was analyzed using SAS v 9.2 (SAS; Cary, NC). Population parameters such as CPUE, CPUE by length and age group, and relative weight were calculated using KDFWR's KFAS and KSLO software run in SAS.

All data was checked for normality using the PROC UNIVARIATE procedure in SAS. Multiple variables were found to be non-normally distributed and have non-constant variance. Additionally, sample sizes were unbalanced for pre-stocking and post-stocking data. As a result, nonparametric analysis of variance (PROC NPAR1WAY) was used to analyze much of the data. This procedure was used to determine if stocking 2.0 in largemouth bass fingerlings could significantly increase catch rate of YOY fish, catch rate of age-1 fish the following spring, and catch rate of fish entering the fishery (12.0 in statewide minimum size limit), as well as to compare growth and catch rates of stocked versus natural largemouth bass. Additionally, multiple linear regression was used to determine if environmental factors were related to natural year-class production in the Ohio River. All data pertaining to river conditions/environmental factors were gathered from gauges maintained by the U.S. Geological Survey. All tests were conducted at $\alpha = 0.05$.

Results

Stocking

A total of 1,403,825 largemouth bass fingerlings were stocked in the Markland Pool, and 134,218 fingerlings were stocked in the Meldahl Pool throughout the course of this study. Stocking rates in the Markland and Meldahl pools of the Ohio River occurred at various rates. Additionally, rates within embayments changed on occasion due to evolving project objectives. All stockings of largemouth bass fingerlings are summarized in Tables 1 and 2.

Sampling

Spring sampling—The Markland Pool received 57.1 hr of effort in multiple embayments throughout the pool. A total of 2,284 largemouth bass were collected for a total project catch rate of 32.0 fish/hr (Table 3). Mean catch rate during pre-stocking years was 10.6 fish/hr, while mean catch rate in post-stocking years was 44.2 fish/hr. Additionally, PSD and RSD of largemouth bass were calculated each spring, but showed no conclusive trends throughout the studY (Table 3). Catch rates were also calculated for four specific length groups. CPUE of largemouth bass <8.0 in ranged from 1.0 fish/hr in 2004 to 18.7 fish/hr in 2012 throughout the study with a mean pre-stocking CPUE of 1.1 fish/hr and mean post-stocking CPUE of 8.1 fish/hr. Mean pre-stocking CPUE of largemouth bass in the 8.0 – 11.9 in length group was 3.7 fish/hr, while mean post-stocking CPUE was 19.9 fish/hr. CPUE for the 8.0 – 11.9 in length group ranged from 1.7 fish/hr in 2005 to 40.7 fish/hr in 2012 throughout the study. Mean pre-stocking CPUE of largemouth bass in the 12.0 – 14.9 in length group was 3.2 fish/hr, and mean post-stocking CPUE was 12.1 fish/hr. CPUE of the 12.0 – 14.9 in length group ranged from 0.6 fish/hr in 2005 to 21.3 fish/hr in 2012 and 2013. CPUE of largemouth bass ≥15.0 in ranged from 1.3 fish/hr in 2006 to 7.6 fish/hr in 2012 throughout the study with a mean pre-stocking CPUE of 2.6 fish/hr and mean post-stocking CPUE of 4.1 fish/hr (Table 4).

The Meldahl Pool received 51.8 hr of effort in multiple embayments throughout the pool. A total of 1,175 largemouth bass were collected for a total catch rate of 15.9 fish/hr (Table 3). Mean catch rate during pre-stocking years was 20.5 fish/hr, while mean catch rate in post-stocking years was 21.2 fish/hr. PSD and RSD showed no noticeable trends throughout the study. Catch rates for four length groups were calculated each spring. CPUE of largemouth bass <8.0 in ranged from 0.3 fish/hr in 2007 to 15.9 fish/hr in 2008 with a mean CPUE of 4.2 fish/hr with a mean pre-stocking CPUE of 3.1 fish/hr and mean post-stocking CPUE of 6.2 fish/hr. Mean CPUE of largemouth bass in the 8.0 – 11.9 in length group was 8.4 fish/hr and ranged from 1.7 fish/hr in 2005 to 25.6 fish/hr in 2008. Mean pre-stocking CPUE of fish in the 8.0 – 11.9 in length group was 8.4 fish/hr and mean post-stocking CPUE was 7.9 fish/hr. Mean pre-stocking CPUE of largemouth bass in the 12.0 – 14.9 in length group was 6.8 fish/hr and mean post-stocking CPUE was 5.5 fish/hr. CPUE of largemouth bass ≥15.0 in ranged from 0.3 fish/hr in 2004 to 9.0 fish/hr in 2008 with a mean pre-stocking CPUE of 2.2 fish/hr and mean post-stocking CPUE of 1.6 fish/hr (Table 4).

Fall sampling—Fall sampling was unable to be conducted in 2006 due to extended high water. A total of 3,128 largemouth bass were collected in 54.6 hr of electrofishing in the Markland Pool throughout the study for a mean CPUE of 57.2 fish/hr (Table 5). Mean pre-stocking CPUE was 30.1 fish/hr, and mean post-stocking CPUE was 59.6 fish/hr. As was done in the spring each year, catch rates were calculated for four specific length groups. CPUE of largemouth bass <8.0 in ranged from 3.0 fish/hr in 2004 to 38.4 fish/hr in 2012 with a mean CPUE of 17.2 fish/hr throughout the study with a mean pre-stocking CPUE of 5.1 fish/hr and mean post-stocking CPUE of 19.1 fish/hr. CPUE of largemouth bass in the 8.0 – 11.9 in length group ranged from 6.7 fish/hr in 2004 to 54.3 fish/hr in 2012 throughout the study with a mean pre-stocking CPUE of 16.7 fish/hr and mean post-stocking CPUE of 26.4 fish/hr. Mean pre-stocking CPUE of largemouth bass 12.0 – 14.9 in was 6.0 fish/hr and mean post-stocking CPUE was 11.2 fish/hr. Catch rates of the 12.0 – 14.9 in length group ranged from 4.7 fish/hr in 2004 to 22.0 fish/hr in 2014 for the entire study. CPUE of largemouth bass ≥15.0 in ranged from 1.2 fish/hr in 2013 to 5.2 fish/hr in 2009 throughout the study with a mean pre-stocking CPUE of 2.3 fish/hr and mean post-stocking CPUE of 2.9 fish/hr (Table 6). Relative weights (Wr) were calculated each fall to see if stocking had any effect on condition of largemouth bass. Overall Wr of largemouth bass in the Markland Pool ranged from 92 in 2013 to 114 in 2005. Wr of four specific length groups were examined. In nearly all years, both pre and post-stocking, Wr of these groups exceeded 100 indicating excellent condition. Wr in 2013 was low for all length groups and exhibited the lowest total Wr of the study (Table 7).

A total of 2,202 largemouth bass were collected in 49.2 hr of electrofishing in the Meldahl Pool throughout the study for a mean CPUE of 44.8 fish/hr (Table 5). Mean pre-stocking CPUE was 35.6 fish/hr, and mean post-stocking CPUE was 56.4 fish/hr. Catch rates were calculated for four specific length groups. CPUE of largemouth bass <8.0 in ranged from 3.1 fish/hr in 2003 to 37.3 fish/hr in 2011 throughout the study with a mean pre-stocking CPUE of 10.1 fish/hr and mean post-stocking CPUE of 23.7 fish/hr. CPUE of largemouth bass in the 8.0 – 11.9 in length group ranged from 5.3 fish/hr in 2010 to 31.0 fish/hr in 2008 throughout the study with a mean pre-stocking CPUE of 14.1 fish/hr and mean post-stocking

CPUE of 21.2 fish/hr. Mean pre-stocking CPUE of largemouth bass 12.0 – 14.9 in was 10.2 fish/hr and mean post-stocking CPUE was 9.7 fish/hr. Catch rates of 12.0 – 14.9 in largemouth bass ranged from 3.9 fish/hr in 2013 to 17.6 fish/hr in 2007. CPUE of largemouth bass ≥15.0 in ranged from 0.7 fish/hr in 2004 to 2.9 fish/hr in 2007 and 2011 with a mean pre-stocking CPUE of 1.2 fish/hr and mean post-stocking CPUE of 1.8 fish/hr (Table 6). Relative weights (Wr) were calculated each fall to see if stocking had any effect on condition of largemouth bass. Overall Wr of largemouth bass in the Meldahl Pool ranged from 92 in 2013 to 112 in 2014. Wr of four specific length groups were examined. In nearly all years, Wr of the 8.0 – 11.9 in and 12.0 – 14.9 in length groups exceeded 100 indicating excellent condition. The ≥15.0 in length group displayed relatively lower Wr in the pre and post-stocking years, but still displayed acceptable levels. As was the case with the Markland Pool, Wr in 2013 was low for all length groups and exhibited the lowest total Wr of the study (Table 7).

<u>Age structure and stocked fish contribution</u>

Age 1+ spring subsample—Otoliths were removed from a subsample of largemouth bass from each embayment every spring except for 2011 when sampling occurred much later than normal due to high water. Up to 10 fish per in class from each embayment were sacrificed, aged, and checked for OTC marks. A total of 765 largemouth bass were aged and checked for OTC marks in the Markland Pool throughout the study. Composition of stocked fish decreased each year after stocking, and stocked fish accounted for 47.7% of largemouth bass collected each spring (Table 8).

A total of 243 largemouth bass were aged and checked for OTC marks in the Meldahl Pool during the study. Stocked fish accounted 39.1% of largemouth bass collected each spring, but did not follow the same trends as the Markland Pool (Table 8).

Young-of-year fall subsample—Otoliths were removed from a subsample of YOY largemouth bass from each embayment each fall. Up to 10 fish per in class from each embayment were sacrificed, aged, and checked for OTC marks. A total of 825 YOY largemouth bass were collected in the Markland Pool throughout the study. Marked fish accounted for at least 38.6% of YOY largemouth bass examined each year and on average accounted for 56.0% of the sample (Table 9). Based on OTC mark results, catch rates were estimated for both natural and stocked YOY largemouth bass. CPUE of natural YOY largemouth bass in the Markland Pool ranged from 0.9 fish/hr in 2013 to 20.9 fish/hr in 2014 with a mean CPUE of 12.2 fish/hr. Mean CPUE of stocked YOY largemouth bass was 13.1 fish/hr, and ranged from 0.9 fish/hr in 2013 to 30.4 fish/hr in 2007 (Table 10).

A total of 208 YOY largemouth bass were collected in the Meldahl Pool throughout the study. Marked fish accounted for at least 45.3% of YOY largemouth bass examined each year and on average accounted for 58.2% of the sample (Table 9). CPUE of natural YOY largemouth bass in the Meldahl Pool ranged from 0.9 fish/hr in 2013 to 18.7 fish/hr in 2014 with a mean CPUE of 11.5 fish/hr. Mean CPUE of stocked YOY largemouth bass was 17.3 fish/hr, and ranged from 4.5 fish/hr in 2013 to 26.2 fish/hr in 2011 (Table 10).

<u>Data analysis</u>

Catch rate—Fall CPUE of YOY largemouth bass in both the Markland (P=0.04) and Meldahl (P<0.01) pools were significantly higher after stockings occurred than in pre-stocking years. Spring CPUE of Age-1 largemouth bass was significantly higher after stockings in the Markland Pool (P=0.03), but the Meldahl Pool (P=0.12) showed no significant changes in catch rates as a result of stocking. Catch rates of largemouth bass entering the fishery (statewide 12.0 in minimum size limit) significantly increased in both the spring (*P*=0.03) and fall (*P*=0.03) in the Markland Pool, but remained indifferent in both the spring (*P*=0.74) and fall (*P*=0.97) in the Meldahl Pool.

Growth and condition—Wr of largemouth bass in the Markland (*P*=0.20) and Meldahl (*P*=0.23) pools was not affected by stocking. Survival of natural YOY largemouth bass was also not affected by stocking in either the Markland (*P*=0.10) or Meldahl (*P*=0.11) pools. Growth rates of natural and stocked YOY largemouth bass were not significantly different in the Markland Pool (*P*=0.31), but stocked fish grew significantly faster in the Meldahl Pool (*P*<0.01).

Environmental factors—Mean, minimum, and maximum April – June discharge, mean, minimum, and maximum April - June temperature, and mean, minimum, and maximum April – June dissolved oxygen were all regressed against fall CPUE of natural YOY largemouth bass to determine if environmental factors had any effect on natural year class production in both the Markland and Meldahl pools. Minimum April – June discharge was the only environmental factors that had any significant correlation with strong natural year class production (*P*=0.05).

Discussion

Fall catch rates of YOY largemouth bass in both the Markland and Meldahl pools of the Ohio River showed significant increases as a result of stocking. Spring catch rates of age-1 fish was significantly higher after stocking in the Markland Pool. This agrees with the earlier findings of Buynak and Mitchell (1999), Heitman et al. (2006) and Colvin et al. (2008) that stocked fish can help supplement YOY and age-1 year classes. The Meldahl Pool did not have increased spring catch rates of age-1 largemouth bass. Catch rates of largemouth bass entering the fishery (≥12.0 in) significantly increased in the spring and fall in the Markland Pool, but not in the Meldahl Pool. These differences in results between pools indicates that there are limiting factors not directly related to stocking affecting the survival of both stocked and natural largemouth bass. Herrala (2013) indicated that high levels of siltation may likely be impacting survival of stocked and natural YOY and age-1 largemouth bass in Ohio River embayments. High siltation can negatively affect spawning success as well as make foraging more difficult, leading to poor survival of YOY and age-1 largemouth bass (Kemp et al. 2011).

Interactions between stocked and natural fish have important implications for stocking success. Terre et al. (1995) found that stocked largemouth bass were more successful in areas with weak natural year classes than in areas with strong natural year classes, likely as a result of competition. Natural year classes in the both the Markland and Meldahl pools are often weak, and may have helped lead to strong contributions to year classes. Stockings did not affect Wr in either the Markland or Meldahl pools, and growth rates were not different between natural and stocked YOY largemouth bass in the Markland Pool; however, stocked YOY fish in the Meldahl Pool grew significantly faster than natural YOY largemouth bass and is concurrent with the findings of Neal et al. (2002) and Messing et al. (2008).

Herrala (2013) noted that environmental factors such as discharge, flood pulse length, siltation, and dissolved oxygen likely play a role in the spawning success of largemouth bass in the Ohio River, and suggested that above average spring flows resulting in high levels of siltation were associated with weak natural year class production. The current study found that natural year class production was inversely related to minimum April – June discharge in the Markland and Meldahl pools, (i.e., low spring flows during the spawn lead to successful natural year class production). This corroborates the findings of Bettoli and Maceina (1998) who found that largemouth bass year class strength was inversely related to late spring discharge on the Tennessee River, and weaker year classes were associated with high flow events after spawning. Conversely, Raibley et al. (2007) found that an extended flood pulse provided stronger year classes on the Illinois River, and that spawning success was associated with prolonged inundation of floodplain habitat that was more conducive to spawning. Inundation of the floodplain in the Markland and Meldahl pools does not provide the habitat as described by Raibley et al. (2007) as indicated by Herrala (2013).

Stocking YOY largemouth bass fingerlings in the Markland and Meldahl pools of the Ohio River has shown to be a success. Catch rates of age-0 fish have increased, while catch rates of keeper (≥12.0 in) fish have remained stable providing a viable recreational fishery for Ohio River anglers. Currently the Department stocks embayments in Kentucky and Indiana waters of the Ohio River. We recommend that stocking be discontinued in Indiana waters and expanded in Kentucky embayments of the Ohio River to provide more opportunities for in-state anglers. Additionally, it is evident that some of the same factors limiting survival of natural YOY largemouth bass also affect stocked YOY largemouth bass (discharge, extended flood pulse, etc.). Many of these factors limiting survival can be combated by the timing of stocking (Hoxmeier and Wahl 2002; Neal et al. 2002). If hatchery space and resources are available, an effort to stock fish in the fall when fish are larger and condition is more favorable for survival would likely help further bolster year class strength.

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Table 1. Stocking sites with acreage, number of largemouth bass fingerlings, and stocking rates for Markland and Meldahl pools of the Ohio River for bass stocked from 2007 - 2014.

					No. of finglerlings stocked by year (stocking rate; fish/acre)								
Pool	No.	Embayment	State	Acres	2007	2008	2009	2010	2011	2012	2013	2014	Total
Markland	1	Craigs Creek	KY	382	40,350 (100)	38,355 (100)	38,408 (100)	38,204 (100)	19,600 (50)	24,966 (65)	18,747 (50)	28,082 (75)	246,712
	2	Turtle Creek	IN	42	4,230 (100)	4,231 (100)	4,247 (100)	4,191 (100)	4,175 (100)	4,172 (100)	4,175 (100)	4,188 (100)	33,609
	3	Bryant Creek	IN	295	29,717 (100)	29,548 (100)	29,601 (100)	29,550 (100)	31,300 (100)	29,549 (100)	29,564 (100)	29,602 (100)	238,431
	4	Big Sugar Creek	KY	24	2,420 (100)	2,463 (100)	2,408 (100)	2,505 (100)	2,430 (100)	2,462 (100)	2,476 (100)	2,474 (100)	19,638
	5	Little Sugar Creek	KY	25	2,609 (100)	2,463 (100)	2,480 (100)	2,504 (100)	2,488 (100)	2,531 (100)	2,555 (100)	2,535 (100)	20,165
	6	Paint Lick Creek	KY	91	10,553 (115)	9,101 (100)	9,139 (100)	9,086 (100)					37,879
	7	Goose Creek	IN	80	8,066 (100)	8,031 (100)	8,098 (100)	7,992 (100)	7,973 (100)	8,003 (100)	8,009 (100)	8,009 (100)	64,181
	8	Big Bone Creek	KY	160	16,002 (100)	16,000 (100)	16,687 (100)	15,955 (100)	8,101 (50)	8,003 (50)	8,017 (50)	8,032 (50)	96,797
	9	Gunpowder Creek	KY	102	5,630 (50)	13,200 (130)	10,332 (100)	10,238 (100)	5,172 (50)	10,260 (100)	10,297 (100)	10,309 (100)	75,438
	10	Grants Creek	IN	98	9,858 (100)	9,840 (100)	9,875 (100)	9,832 (100)	9,835 (100)	9,850 (100)	9,883 (100)	9,870 (100)	78,843
	11	Arnold Creek	IN	80	8,140 (100)	8,176 (100)	7,993 (100)	8,010 (100)	7,985 (100)	8,003 (100)	8,017 (100)	8,032 (100)	64,356
	12	Woolper Creek	KY	58	4,910 (85)	6,400 (110)	5,826 (100)	5,761 (100)					22,897
	13	Laughery Creek	IN	119	12,098 (100)	13,400 (110)	11,969 (100)	11,900 (100)	11,862 (100)	11,902 (100)	11,935 (100)	12,530 (100)	97,596
	14	N. and S. Hogan Creek	IN	93	10,000 (110)	9,570 (100)	9,393 (100)	9,718 (100)	9,374 (100)	9,302 (100)	9,354 (100)	9,326 (100)	76,037
	15	Tanners Creek	IN	109	11,500 (100)	10,907 (100)	11,060 (100)	10,905 (100)	10,878 (100)	10,876 (100)	10,906 (100)	10,896 (100)	87,928
	16	Licking River	KY	286	28,728 (100)	28,632 (100)	28,684 (100)	28,574 (100)	28,700 (100)				143,318
		Total		2,042	204,811	210,317	206,200	204,925	159,873	139,879	133,935	143,885	1,403,825
Meldahl	1	Big Snag Creek	KY	38					3,809 (100)	3,830 (100)	3,834 (100)	3,853 (100)	15,326
	2	Big Locust Creek	KY	84					8,457 (100)	8,413 (100)	8,435 (100)	8,416 (100)	33,721
	3	Big Turtle Creek	KY	27					5,409 (200)	5,404 (200)	5,410 (200)	5,408 (200)	21,631
	4	Bracken Creek	KY	79					7,923 (100)	7,934 (100)	8,009 (100)	7,943 (100)	31,809
	5	Lees Creek	KY	56					5,638 (100)	5,609 (100)	5,895 (100)	5,600 (100)	22,742
	6	Lawrence Creek	KY	22					2,209 (100)	2,257 (100)	2,258 (100)	2,265 (100)	8,989
		Total		306					33,445	33,447	33,841	33,485	134,218

Table 2. Stocking totals of largemouth bass fingerlings for Markland and Meldahl pools in the Ohio River 2007-2014.

Pool	Year	Month	Number embayments stocked	Number fingerlings	Average length (in)
Markland	2007	June	16	204,811	1.9
	2008	June	16	210,317	1.9
	2009	July	16	206,200	1.8
	2010	June	16	204,925	2.0
	2011	June	14	159,873	1.8
	2012	May	13	139,879	1.5
	2013	June	13	133,935	1.9
	2014	June	13	143,885	2.1
	Total			1,403,825	1.9
Meldahl	2011	June	6	33,445	1.6
	2012	May	6	33,447	1.5
	2013	May	6	33,841	1.8
	2014	June	6	33,485	1.9
	Total			134,218	1.7

Table 3. Electrofishing effort and CPUE (fish/hr), PSD, and RSD of largemouth bass collected from the Markland and Meldahl pools of the Ohio River in spring 2003 - 2014. Standard errors are in parentheses.

Pool	Stocking	Year	Effort (hr)	No. of largemouth bass	CPUE	PSD	RSD
Markland	Pre	2004	3.1	53	17.7 (6.3)	55	23
		2005	3.1	21	6.0 (2.1)	25	4
		2006	4.5	50	11.1 (2.9)		
		2007	6.0	347	8.9 (4.2)	35	7
		Total	16.7	471			
		Mean			10.6 (2.5)	38	11
	Post	2008	6.0	340	55.6 (6.2)	28	10
		2009	6.0	221	36.1 (5.0)	45	7
		2010	6.0	174	28.4 (4.4)	52	17
		2011	5.0	98	19.2 (2.8)	66	19
		2012	5.8	510	88.2 (8.5)	41	11
		2013	5.8	345	59.5 (5.5)	49	6
		2014	5.8	125	21.6 (2.8)	56	21
		Total	40.4	1,813			
		Mean			44.2 (3.9)	48	13
Meldahl	Pre	2003	7.5	275	36.7 (7.8)	58	11
		2004	4.0	15	4.0 (1.2)	67	17
		2005	3.0	29	6.1 (1.6)	41	5
		2006	2.5	27	10.8 (4.7)		
		2007	2.8	44	14.7 (6.3)	59	8
		2008	3.8	220	57.8 (6.4)	53	16
		2009	3.8	111	29.6 (5.6)	44	13
		2010	3.8	70	18.7 (4.3)	69	20
		2011	3.8	31	8.3 (2.2)	63	21
		Total	35.0	822			
		Mean			20.5 (2.6)	57	14
	Post	2012	5.5	133	23.7 (4.0)	48	15
		2013	5.3	169	31.9 (4.0)	51	9
		2014	6.0	48	8.0 (1.6)	36	10
		Total	16.8	350			
		Mean			21.2 (2.9)	45	11

Table 4. Spring electrofishing catch-per-unit-effort (fish/hr) for four length groups of black bass from Markland and Meldahl pools of the Ohio River from 2003-2014. Standard errors are in parentheses.

			Length group				
Pool	Stocking	Year	<8.0 in	8.0-11.9 in	12.0-14.9 in	≥15.0 in	Total
Markland	Pre	2004	1.0 (0.3)	5.0 (0.7)	6.0 (0.9)	5.7 (0.5)	17.7 (6.3)
		2005	1.7 (1.5)	1.7 (1.5)	0.6 (0.6)	2.0 (1.3)	6.0 (2.1)
		2006	1.1 (0.7)	5.1 (2.1)	3.6 (1.9)	1.3 (0.9)	11.1 (2.9)
		2007	1.4 (1.1)	3.3 (2.0)	2.6 (2.1)	1.7 (1.3)	8.9 (4.2)
		Mean	1.1 (0.2)	3.7 (0.8)	3.2 (1.1)	2.6 (1.0)	10.6 (2.5)
	Post	2008	12.2 (3.2)	32.5 (5.7)	8.9 (2.1)	5.4 (2.5)	49.0 (5.9)
		2009	9.5 (2.8)	14.5 (3.9)	10.1 (2.3)	2.0 (1.0)	36.1 (5.0)
		2010	3.8 (1.6)	11.8 (3.1)	8.8 (2.6)	4.1 (1.4)	28.4 (4.4)
		2011	3.7 (1.0)	5.3 (1.2)	7.3 (1.3)	2.9 (0.8)	19.2 (2.8)
		2012	18.7 (2.9)	40.7 (4.1)	21.3 (3.7)	7.6 (1.33)	88.2 (8.5)
		2013	7.9 (1.4)	25.7 (3.0)	21.3 (2.9)	2.9 (0.9)	59.5 (5.5)
		2014	1.4 (0.6)	8.8 (1.3)	7.3 (1.4)	4.1 (1.7)	21.6 (2.8)
		Mean	8.1 (0.9)	19.9 (2.0)	12.1 (1.0)	4.1 (0.3)	44.2 (3.9)
Meldahl	Pre	2003	5.7 (0.7)	12.4 (1.7)	14.8 (1.0)	3.8 (0.5)	36.7 (7.8)
		2004	0.8 (0.6)	2.4 (0.4)	0.5 (0.3)	0.3 (0.3)	4.0 (1.2)
		2005	1.3 (0.9)	1.7 (1.1)	2.5 (1.1)	0.6 (0.6)	6.1 (1.6)
		2006	3.2 (2.6)	4.8 (3.2)	2.0 (1.4)	0.8 (0.8)	10.8 (4.7)
		2007	0.3 (0.3)	6.7 (3.9)	6.3 (4.6)	1.3 (0.9)	14.7 (6.3)
		2008	15.9 (4.2)	25.6 (6.0)	18.8 (4.6)	9.0 (4.1)	62.9 (6.4)
		2009	1.3 (0.9)	15.7 (4.7)	8.8 (3.2)	3.7 (2.0)	29.6 (5.6)
		2010	1.3 (1.2)	5.3 (2.5)	8.5 (2.7)	3.5 (1.9)	18.7 (4.3)
		2011	1.9 (1.0)	2.4 (1.1)	2.7 (0.8)	1.3 (0.7)	8.3 (2.2)
		Mean	3.1 (0.7)	8.4 (1.2)	6.8 (0.9)	2.2 (0.4)	20.5 (2.6)
	Post	2012	9.8 (1.8)	7.1 (1.4)	4.6 (1.1)	2.1 (0.7)	23.7 (4.0)
		2013	7.4 (2.1)	11.6 (2.2)	10.1 (1.7)	2.0 (0.6)	31.9 (4.0)
		2014	1.0 (0.4)	4.5 (0.9)	1.8 (0.5)	0.7 (0.4)	8.0 (1.6)
		Mean	6.2 (1.1)	7.9 (0.8)	5.5 (1.0)	1.6 (0.2)	21.2 (2.9)

Table 5. Electrofishing effort and CPUE (fish/hr) of largemouth bass collected from the Markland and Meldahl pools of the Ohio River in fall 2003 - 2014. Standard errors are in parentheses.

Pool	Stocking	Year	Effort (hr)	No. of largemouth bass	CPUE
Markland	Pre	2004	3.0	53	17.7 (6.3)
		2005	4.5	191	42.4 (13.3)
		2006			
		Total	7.5	244	
		Mean			30.1 (4.4)
	Post	2007	5.8	347	57.7 (6.1)
		2008	5.8	333	45.7 (7.7)
		2009	5.8	214	37.0 (5.5)
		2010	5.8	322	52.6 (8.2)
		2011	6.8	405	59.6 (8.8)
		2012	5.8	673	116.4 (12.7)
		2013	5.5	159	28.9 (3.3)
		2014	5.8	431	74.3 (8.0)
		Total	47.1	2,884	
		Mean			59.6 (3.9)
Meldahl	Pre	2003	3.5	73	20.8 (3.0)
		2004	3.8	116	30.5 (6.2)
		2005	3.8	229	60.3 (23.2)
		2006			
		2007	4.4	263	58.4 (13.5)
		2008	3.8	125	33.3 (7.4)
		2009	3.8	58	15.5 (3.8)
		2010	3.8	89	23.5 (4.2)
		Total	26.9	953	
		Mean			35.6 (2.8)
	Post	2011	5.5	395	70.6 (7.7)
		2012	5.5	361	66.4 (6.3)
		2013	5.8	159	27.9 (4.0)
		2014	5.5	334	60.7 (6.8)
		Total	22.3	1,249	
		Mean			56.4 (4.0)

Table 6. Fall electrofishing catch-per-unit-effort (fish/hr) for four length groups of black bass from Markland and Meldahl pools of the Ohio River from 2003-2014. Standard errors are in parentheses.

			Length group				
Pool	Stocking	Year	<8.0 in	8.0-11.9 in	12.0-14.9 in	≥15.0 in	Total
Markland	Pre	2004	3.0 (0.5)	6.7 (0.9)	4.7 (0.8)	3.3 (0.5)	17.7 (6.3)
		2005	7.1 (3.9)	26.7 (10.2)	7.3 (2.0)	1.3 (1.2)	42.4 (13.3)
		2006					
		Mean	5.1 (0.7)	16.7 (3.5)	6.0 (0.5)	2.3 (0.4)	30.1 (4.4)
	Post	2007	18.6 (4.4)	25.6 (4.8)	10.7 (3.2)	2.8 (1.3)	57.7 (6.1)
		2008	18.9 (6.7)	27.4 (5.3)	8.1 (2.1)	2.0 (1.1)	45.7 (7.7)
		2009	8.0 (2.6)	15.2 (4.4)	8.7 (2.6)	5.2 (1.9)	37.0 (5.5)
		2010	24.7 (5.7)	18.1 (4.8)	7.0 (2.2)	2.8 (1.4)	52.6 (8.2)
		2011	18.1 (3.3)	27.8 (4.9)	10.4 (1.8)	3.2 (1.1)	59.6 (8.8)
		2012	38.4 (5.3)	54.3 (7.4)	20.1 (2.9)	3.6 (0.8)	116.4 (12.7)
		2013	4.7 (1.6)	16.4 (2.4)	4.8 (1.2)	1.2 (0.4)	28.9 (3.3)
		2014	21.4 (3.1)	28.3 (3.9)	22.0 (3.5)	2.6 (0.8)	74.3 (8.0)
		Mean	19.1 (1.5)	26.4 (1.8)	11.2 (0.9)	2.9 (0.2)	59.6 (3.9)
Meldahl	Pre	2003	3.1 (1.8)	11.1 (2.3)	4.3 (0.9)	2.3 (0.9)	20.8 (3.0)
		2004	8.3 (4.3)	7.1 (2.7)	14.4 (4.5)	0.7 (0.6)	30.5 (6.2)
		2005	18.0 (6.3)	23.9 (11.4)	16.5 (6.6)	2.0 (1.1)	60.3 (23.2)
		2006					
		2007	23.8 (8.2)	14.2 (4.9)	17.6 (4.2)	2.9 (1.8)	58.4 (13.5)
		2008	4.4 (2.3)	31.0 (8.0)	9.9 (3.8)	1.5 (1.3)	33.3 (7.4)
		2009	3.7 (1.7)	5.9 (2.5)	4.5 (2.4)	1.3 (0.9)	15.5 (3.8)
		2010	9.4 (3.4)	5.3 (2.8)	6.4 (2.2)	2.4 (1.4)	23.5 (4.2)
		Mean	10.1 (1.2)	14.1 (1.5)	10.2 (0.9)	1.2 (0.1)	35.6 (2.8)
	Post	2011	37.3 (5.6)	20.1 (2.4)	10.3 (2.1)	2.9 (0.7)	70.6 (7.7)
		2012	23.9 (3.9)	30.2 (3.9)	10.5 (1.7)	1.8 (0.6)	66.4 (6.3)
		2013	7.0 (1.3)	16.0 (2.1)	3.9 (0.9)	1.4 (0.5)	27.9 (4.0)
		2014	26.4 (4.6)	19.1 (3.2)	14.2 (2.4)	1.0 (0.6)	60.7 (6.8)
		Mean	23.7 (2.6)	21.2 (1.3)	9.7 (0.9)	1.8 (0.2)	56.4 (4.0)

Table 7. Relative weight (Wr) by length group estimates for each species of black bass collected from Markland and Meldahl pools in the Ohio River from fall 2003-2014.

			Relative weight (Wr) length group			
Pool	Stocking	Year	8.0-11.9 in	12.0-14.9 in	$\geq$15.0 in	Overall
Markland	Pre	2004	102	99	101	101
		2005	115	111	107	114
		2006				
		Mean	109	105	104	108
	Post	2007	106	106	109	106
		2008	101	98	100	101
		2009	97	94	101	97
		2010	101	103	100	102
		2011	100	97	105	100
		2012	107	106	103	107
		2013	91	95	98	92
		2014	107	103	106	105
		Mean	101	100	103	101
Meldahl	Pre	2003	100	92	97	98
		2004	104	97	101	100
		2005	111	109	113	110
		2006				
		2007	106	105	103	105
		2008	107	101	88	105
		2009	96	92	93	94
		2010	110	105	99	106
		Mean	105	100	99	103
	Post	2011	106	109	107	107
		2012	112	108	103	111
		2013	92	95	91	92
		2014	119	104	83	112
		Mean	107	104	96	106

Table 8. Subsample of age 1+ largemouth bass otoliths checked for OTC marks from each study embayment in Markland and Meldahl pools of the Ohio River from spring 2008 - 2014.

	Markland															
	2008		2009		2010		2011		2012		2013		2014		Total	
Age	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked
1	76	23	22	16	8	13			18	27	37	46	8	28	169	153
2			55	23	28	23			21	24	20	52	13	26	137	148
3					29	33			2	6	20	19	5	11	56	69
4										1		11	2	6	2	18
5											1	2		1	1	3
6												3		4		7
7														2		2
n	76	23	77	39	65	69			41	58	78	133	28	78	365	400
%	76.8	23.2	66.4	33.6	48.5	51.5			41.4	58.6	37.0	63.0	26.4	73.6	47.7	52.3

	Meldahl															
	2008		2009		2010		2011		2012		2013		2014		Total	
Age	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked
1									31	29	19	28	11	13	61	70
2									2	21	22	25	9	10	33	56
3											1	21		1	1	22
n									33	50	42	74	20	24	95	148
%									39.8	60.2	36.2	63.8	45.5	54.5	39.1	60.9

Table 9. Subsample of age 0 largemouth bass otoliths checked for OTC marks from each study embayment in Markland and Meldahl pools of the Ohio River from fall 2007 - 2014.

	Markland																	
	2007		2008		2009		2010		2011		2012		2013		2014		Total	
Inch class	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked
3	3									2							3	2
4	7	4	1		10	8	5	13	2	12		9	3	1	2	8	30	55
5	2	3	4	6	10	6	9	12	7	19	2	11	1	2	6	11	41	70
6	28	12	7	6	5	2	14	13	9	19	8	24		2	19	12	90	90
7	51	10	7	11	1	1	13	13	20	16	22	11	1		7	10	122	72
8	56	7	12	10			3	2	6	2	10	3			7	3	94	27
9	18	4	13	12												2	31	18
10		3	20	8												1	20	12
11			16	9													16	9
12			13	5													13	5
13			2	3													2	3
n	165	43	95	70	26	17	44	53	44	70	42	58	5	5	41	47	462	363
%	79.3	20.7	57.6	42.4	60.5	39.5	45.4	54.6	38.6	61.4	42.0	58.0	50.0	50.0	46.6	53.4	56.0	44.0

	Meldahl																	
	2007		2008		2009		2010		2011		2012		2013		2014		Total	
Inch class	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked
3												4						4
4												5	8	3		3	8	11
5											6	11	13		4	14	23	25
6											16	3	4	2	10	22	30	27
7											20	6			13	8	33	14
8											9	1			13	5	22	6
9											2				3		5	
n											53	30	25	5	43	52	121	87
%											63.9	36.1	83.3	16.7	45.3	54.7	58.2	41.8

Table 10. Fall catch-per-unit-effort (fish/hr) estimates and mean lengths for naturally reproduced and stocked age-0 largemouth bass from the Markland and Meldahl pools of the Ohio River in fall 2007-2014. Standard errors are in parentheses.

		Natural		Stocked		Total	%
Pool	Year-class	CPUE	Mean length	CPUE	Mean length	CPUE	Stocked
Markland	2007	10.7 (0.3)	7.3	30.4 (1.0)	7.6	41.1 (0.1)	74.0
	2008	5.7 (0.2)	6.2	8.3 (0.2)	6.6	14.0 (0.3)	59.3
	2009	3.0 (0.2)	5.2	4.8 (0.2)	5.3	7.8 (0.4)	61.5
	2010	14.0 (0.6)	6.0	12.2 (0.7)	6.5	26.2 (1.2)	46.6
	2011	11.9 (0.6)	6.1	7.8 (0.4)	6.9	19.7 (0.9)	38.6
	2012	30.7 (1.5)	6.3	22.2 (2.8)	7.6	52.9 (3.5)	38.1
	2013	0.9 (0.1)	5.7	0.9 (0.1)	5.2	1.7 (0.1)	37.5
	2014	20.9 (0.9)	6.4	18.2 (0.8)	6.8	39.1 (0.9)	46.6
	Mean	12.2 (0.2)	6.2	13.1 (0.3)	6.6	39.1 (0.4)	50.3
Meldahl	2011	13.3 (0.6)	5.6	26.2 (1.5)	6.5	39.5 (2.0)	63.3
	2012	13.1 (0.3)	5.4	23.1 (1.3)	7.1	36.3 (1.2)	63.9
	2013	0.9 (0.2)	5.4	4.5 (0.5)	5.4	5.4 (0.4)	83.3
	2014	18.7 (1.1)	6.4	15.5 (0.9)	7.5	34.2 (1.6)	45.3
	Mean	11.5 (0.2)	5.7	17.3 (0.2)	6.6	28.9 (0.3)	64.0