Stocking Threadfin Shad to Enhance Largemouth Bass Populations in Two Alabama Ponds

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Abstract: Increasingly, new innovative management approaches are being used in small ponds that contain largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) to increase the quality of largemouth bass fisheries. One approach is to stock additional forage fish. Threadfin shad (*Dorosoma petenense*) were stocked into two small Alabama ponds (1.9 and 5.3 ha) in 2007, 4 yrs after renovation and restocking with largemouth bass and bluegill (1:15 stocking ratio) to improve largemouth bass relative weight (W_r) and length distributions. Threadfin shad inhabited these two ponds for about 2.5 yrs before being eliminated by severe winter temperatures in January 2010. After threadfin shad became established, W_r increased for stock- and quality-length (203–380 mm) largemouth bass, but not for preferred-length and larger (>380 mm) fish. Proportional size distributions (PSD, PSD-P), which declined prior to threadfin shad stocking, increased as largemouth bass recruitment to stock length declined. Following a winterkill of threadfin shad, W_r of all sizes of largemouth bass and PSD indices declined and largemouth bass recruitment increased. Relative weights of quality-length (>151 mm) bluegill declined during threadfin shad presence, and we speculate this was due to higher bluegill densities as largemouth bass predation on bluegill was likely less. Stocking threadfin shad into two established largemouth bass-bluegill ponds provided for improved largemouth bass populations, but may sacrifice quality bluegill fisheries.

Key words: bluegill, proportional size distributions, relative weight

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Management of small (<40 ha) impoundments for recreational sport fishing has recently received renewed interest (Neal and Willis 2012). Historically, assessments, stocking, and management of both privately- and publicly-owned sport fish ponds were primarily provided by state fish conservation agencies. However, many successful private businesses have emerged over the past 25 yrs that provide unique management practices that cater to specific client goals for fishing (Neal and West 2012). Reviews provided by Dauwalter and Jackson (2005) and Willis et al. (2010) suggest that traditional management of sport fisheries are changing, with new and innovative approaches taking place. Whereas most common pond management strategies in the past commonly involved stocking only largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*), today additional species are often stocked in ponds to achieve specific objectives (Willis et al. 2010). Although overharvest of fish was once a primary issue, in many instances today, lack of harvest causes management problems (Willis and Neal 2012). In the past, small sport fish ponds provided recreational opportunities as well as food, but increasingly, anglers fishing these water bodies desire catching larger fish for sport and fish consumption is less of a priority.

When only largemouth bass and bluegill have been stocked in ponds, lack of harvest can lead to largemouth bass overcrowding, resulting in stunted growth and poor body condition, and a population skewed towards smaller fish (Schramm and Willis 2012). Even liberal largemouth bass harvest rates of 10–20 kg ha^{-1} may not be sufficient to reduce the density of these fish to improve growth and size structure. Sammons and Maceina (2005) found consumption by small (< 25 cm TL) largemouth bass on bluegill in small Alabama ponds was very high and reduced bluegill available to largemouth bass for prey, which could lead to stunting. To augment and increase prey resources for largemouth bass, other fish species have been stocked to improve the growth and size structure of these predatory fish, including threadfin shad (*Dorosoma petenense*), gizzard shad (*D. cepedianum*), fathead minnow (*Pimephales promelas*), golden shiner (*Notemigonus crysoleucas*), lake chubsucker (*Erimyzon sucetta*), and various tilipia (*Oreochromis* spp.) species (Wright and Kraft 2012). Some of these non-traditional forage fish stockings can improve recreational fishing, while others have no impact, or cause detrimental effects.

Threadfin shad is probably the most common fish stocked to enhance predators such as largemouth bass in the southern United States (Noble 1981, DeVries and Stein 1990). Threadfin shad are considered an ideal forage fish as reproduction is prolific, maximum length is about 175 mm, and their narrow body permits greater predation availability compared to bluegill. Largemouth bass can consume up to half the body length of a threadfin shad compared to only a third of its body length for bluegill or other lepomid sunfish (Lawrence 1961). However, at times threadfin shad populations are not sustainable in shallow ponds in southern states as water temperatures less than 5 C can cause complete winter kills (Strawn 1963). Also, non-lethal, low water temperatures can impair swimming ability of threadfin shad, increasing their vulnerability to predation to the point that virtual extirpation may be possible in small ponds.

DeVries and Stein (1990) surveyed available literature and concluded that the success or failure of both threadfin shad and gizzard shad introductions and removals were mixed. In general, predator fish generally benefitted from shad presence, but shad exerted a negative impact on bluegill (DeVries and Stein 1990). In a survey of 66 ponds in Alabama, Haley et al. (2012) found that in fertilized ponds stocked with threadfin shad, largemouth bass displayed higher relative weights and greater sizes compared to those ponds which were not stocked with threadfin shad. In this paper, we examined largemouth bass populations prior to, during threadfin shad establishment, and after threadfin shad die off due to a winter kill in two Alabama ponds. We also examined the relation between threadfin shad stocking and bluegill relative weight in these ponds. Our management goal was to produce quality largemouth bass fisheries with proportional size distributions (PSD) skewed towards larger individuals (PSD-Preferred Length values >40) and maintain average relative weights over 90.

Methods

Pond Description, Stockings, and Pond Maintenance

The two ponds used for this study were located on the E. W. Shell North Auburn University Fisheries Station and were part of the previously mentioned study by Sammons and Maceina (2005). Ponds S-28 and S-30 were 1.9 and 5.3 ha, respectively, and were renovated in January 2003. Bluegill (mean weight 1.4 g) were stocked in March 2003 at a rate of 3700 fish ha^{-1}. This stocking rate was 50% higher than the rate recommended by Swingle (1951) because we attempted to maximize food resources for largemouth bass. After bluegill spawned in spring 2003, the ponds were stocked with largemouth bass (F_1 northern largemouth bass [*M. s. salmoides*] × Florida largemouth bass [*M. s. floridanus*] mean 50 mm total length [TL]) at a rate of 247 ha^{-1} following the recommended stock rate proposed by Swingle (1951). Fish were obtained from American Sportfish Hatchery (Montgomery, Alabama). Throughout the duration of this study, water-soluble fertilizer (10-52-4) was applied during the growing season (March to October) to enhance phytoplankton growth with a goal to maintain water clarity at 0.5 to 0.7 m, measured with a Secchi disk.

From 2005 to 2011, we harvested an average of 14 and 15 kg ha^{-1} yr^{-1} of largemouth bass using electrofishing and angling from S-28 and S-30, respectively. Most of these fish (92%) were less than 351 mm TL. As mentioned previously, we established an initial goal to maintain largemouth bass relative weights (standard weight equation of Anderson and Neumann 1996) of 90 or higher, which we considered to confer average body condition. Coincident with this goal, we wanted to achieve a largemouth bass proportional size distribution of preferred length fish of 40 (PSD – P = N fish ≥381 mm TL/ N fish ≥203 mm TL × 100) that typically would not be found in a balanced largemouth bass – bluegill pond population (Schramm and Willis 2012). By fall 2006, largemouth bass relative weights were less than 90 and a decision was made to stock threadfin shad in these ponds in 2007. In June 2007, an estimated 2000 (1052 fish ha^{-1}) and 4000 (755 fish ha^{-1}) threadfin shad (mean 100 mm TL) were stocked into ponds S-28 and S-30, respectively.

Fish Sampling

Largemouth bass and bluegill were collected with DC electrofishing twice each year (spring, March–April and fall, October–November) from October 2003 to April 2011. Sampling did not occur every fall due to low pond water levels during dry years that inhibited boat access. During each sampling event, three random electrofishing shoreline transects were completed and all largemouth bass were collected for 10 min along each transect. Bluegill were also collected for the first 5 min along each of these transects. All largemouth bass and bluegill quality size and larger (≥152 mm TL) were measured for total length (mm TL), weighed (g), and released. After threadfin became established in these ponds by fall 2007, we observed these fish while electrofishing, but did not enumerate or process these fish. In addition, threadfin shad schools were observed in both ponds through fall 2009. In January 2010, for about a two-week period, ambient air temperatures did not rise above 3 C, air temperatures at or below –4 C were common, and ice formed at the edge of these ponds. Following this event, threadfin shad were not detected during electrofishing surveys and were not visibly observed for the remainder of the project. We assumed all threadfin shad died during this extreme weather event.

Data Analyses

Data were pooled across ponds and PSD (N fish ≥304 mm TL/ N fish ≥203 mm TL × 100) and PSD-P (defined earlier) were computed for largemouth bass for each sampling event following the criteria of Neumann et al. (2012). Relative weights (W_r) were computed for stock (203–303 mm TL), quality (304–380 mm TL), and preferred length and longer (≥381 mm TL) largemouth bass and for quality (152–203 mm TL) and preferred length (≥204 mm TL) bluegill using recently published standard weight equations (Neumann et al. 2012). Relative weights were plotted for each sampling event and compared over time for four distinct time events. These included 1) new: from 2004 to spring 2006 when we observed that largemouth bass and bluegill W_r values were adequate to high; 2) pre-threadfin shad: fall 2006 through spring 2007 largemouth bass W_r declined rapidly compared to the first three years; 3) threadfin shad presence: from fall 2007 to fall 2009; and 4) post-threadfin shad (die off); from spring 2010 through spring 2011. Relative weights estimated for each species and size group were tested for differences using a fixed-model analysis-of-variance (ANOVA) that included these four treatment time intervals, season (spring and fall), and pond (S-28 and S-30) effects (SAS Institute 2008).

Proportional size distributions can vary greatly if recruitment is inconsistent (Schramm and Willis 2012). Thus, we computed electrofishing catch-per-effort (fish min^{-1}) for stock and substock (≤202 mm TL) largemouth bass in each pond for each transect and sampling event. For this analysis, three distinct time periods or treatment intervals were compared and included 1) pre-threadfin shad introduction from fall 2004 (largemouth bass reproduction first detected) through spring 2007; 2) threadfin shad presence from fall 2007 through spring 2010; and 3) post-threadfin shad die off from fall 2010 through spring 2011. Besides treatment interval, the effects of ponds (S-28 and S-30), season (spring and fall), and size (substock- or stock-length) on catch-per-effort were tested in the four-way ANOVA (SAS Institute 2008). Catch-per-effort data were transformed to log_{10} values prior to analysis. For all analyses, differences in mean values were delineated with the Student-Neumann-Kuels test ($P < 0.05$).

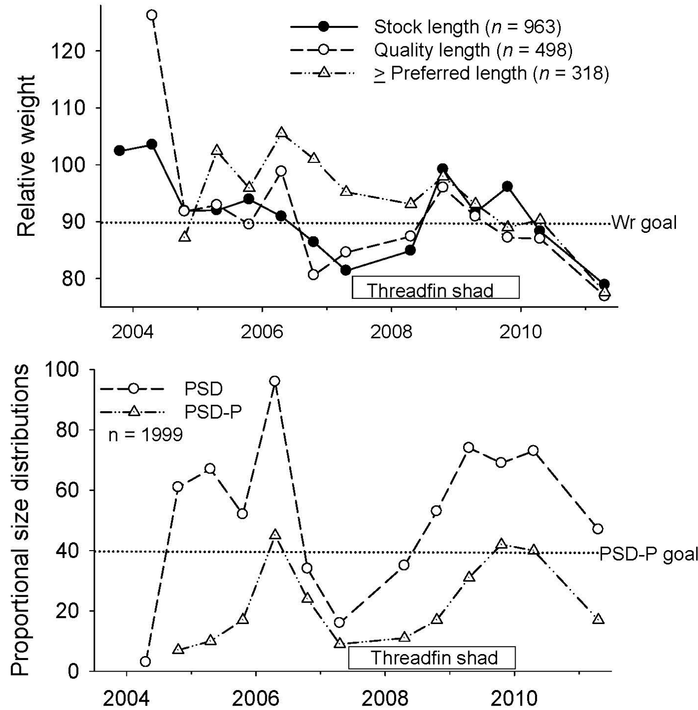

Figure 1. Mean relative weights of stock-, quality-, and preferred- and longer length groups for largemouth bass collected from two Auburn University ponds Fall 2003 to Spring 2011 (top graph). Proportional size distributions for largemouth bass collected from these ponds were plotted over time (bottom graph). The time period for the presence of threadfin shad in each pond is shown in the rectangles. Relative weight and PSD-P goals are represented by the dotted lines. Sample sizes (*n*) are given.

Results

During the first three years following stocking, largemouth bass W_r values were initially greater than 90, and PSD and PSD-P indices rose rapidly (Figure 1). By spring 2006, our PSD-P goal of 40 was achieved. From electrofishing catch rates of substock- and stock-length fish, recruitment of these fish increased in spring 2006 and 2007 (Figure 2), and W_r of all sizes of largemouth bass declined and PSD and PSD-P decreased in fall 2006 and spring 2007. Threadfin shad were introduced into both ponds in summer 2007 and by spring 2008, W_r of stock- and quality-length largemouth bass increased. After 2007, electrofishing catch of substock- and stock-length largemouth bass were generally lower between 2008 and 2010, and PSD and PSD-P both increased during this time. By fall 2009, PSD-P again exceeded 40. Threadfin shad disappeared from the ponds by spring 2010, W_r of all sizes of largemouth bass dropped rapidly below our goal of 90, and electrofishing catch rates of substock- and stock-length largemouth bass increased in S-30 (Figures 1 and 2). Proportional size distributions also declined by spring 2011 after the threadfin shad winter kill (Figure 1).

Statistical analyses confirmed these trends over time; catch rates of substock- and stock-length largemouth bass declined ($F = 3.80$; $P < 0.05$) by about 50% during threadfin shad presence, but increased one year after the shad die off (Figure 3). Three years after the initial stocking of largemouth bass and bluegill, W_r of all sizes of largemouth bass declined, but W_r values of stock- and quality-length fish increased following shad introduction (F range = 18.7 to 165.5; $P < 0.0001$). After the threadfin shad winter kill, W_r of all sizes of largemouth bass decreased (Figure 1). Although relative weights of preferred-length and longer largemouth bass declined slightly after threadfin shad introductions, our W_r goal of 90 was maintained, but average W_r decreased to less than 90 after the threadfin shad die off ($F = 18.7$; $P < 0.0001$).

Although treatment intervals for threadfin shad occurrence was related to electrofishing catch rates of substock- and stock-length largemouth bass, catch rates varied between ponds ($F = 14.1$; $P < 0.001$) and averaged about 70% higher in S-30 (Figure 2). A pond-treatment interval interaction was evident ($F = 5.68$; $P < 0.01$) as catch rates of substock- and stock-length largemouth bass were higher in S-30 after threadfin shad winter-kill than in S-28 (Figure 2). Season or fish size (substock- or stock-length) had no influence on catch rates of these small fish ($P > 0.4$). Among the three size groups of largemouth bass tested for W_r, differences among treatments, numerous significant ($P < 0.05$) single and two-way interactions effects were detected. Most common were treatment-by-season effects ($F = 4.66$ to 35.1; $P \leq 0.01$) as higher W_r values were observed in both spring and fall during various treatment intervals. For two of the three size groups, significant ($F = 5.30$ and 33.1; $P < 0.001$) pond-by-treatment interactions were detected and indicated that W_r varied between ponds over treatment intervals. Nevertheless, based on Type III sum of squares in these ANOVAs, treatment interval was always the strongest variable that explained differences in W_r among three size groups of largemouth bass.

After threadfin shad were stocked into each pond, relative weights declined (F range = 10.1 to 13.3; $P < 0.0001$) for quality- and preferred-length bluegill (Figure 3). After the threadfin shad winter kill, W_r increased for quality-length bluegill, but remained depressed for preferred-length fish. For both quality- and preferred-length bluegill, W_r values were slightly higher ($F = 6.03$ to 6.48; $P < 0.02$) in the spring compared to the fall. Besides treatment intervals and seasons, other single, two-way, and three-way interaction effects were not statistically ($P > 0.05$) detected.

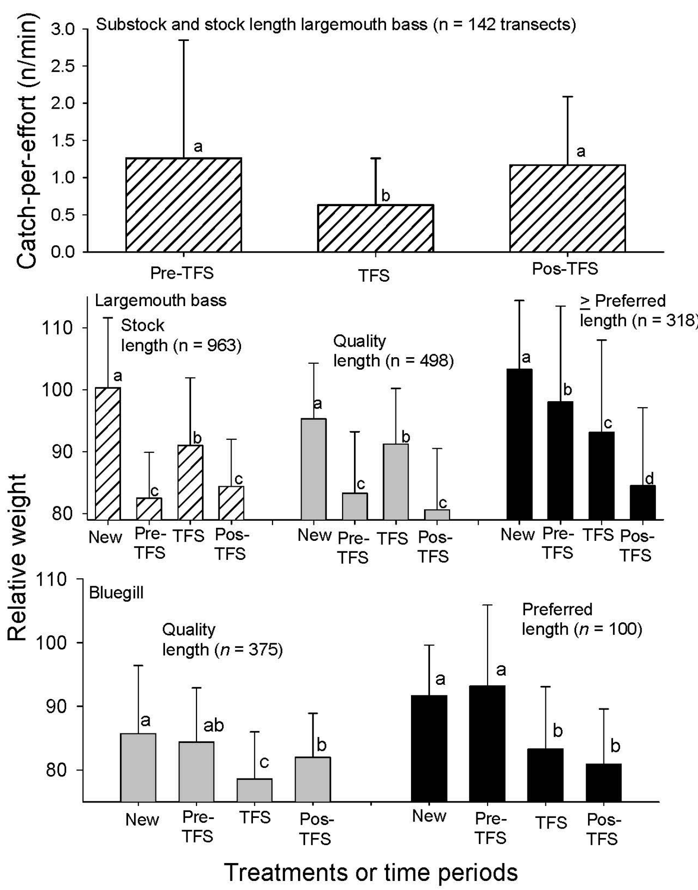

Figure 3. Mean electrofishing catch rates of substock- and stock-length largemouth in two Auburn University ponds during three time intervals or treatment phases (top graph). The total number (*n*) of electrofishing transects is given. Mean relative weights of various length groups of largemouth bass (middle graph) and bluegill (bottom graph) were plotted during three time intervals or treatment phases and total number (*n*) of fish collected are given. For all comparisons in each graph, mean values followed by the same letter were not statistically ($P > 0.05$) different.

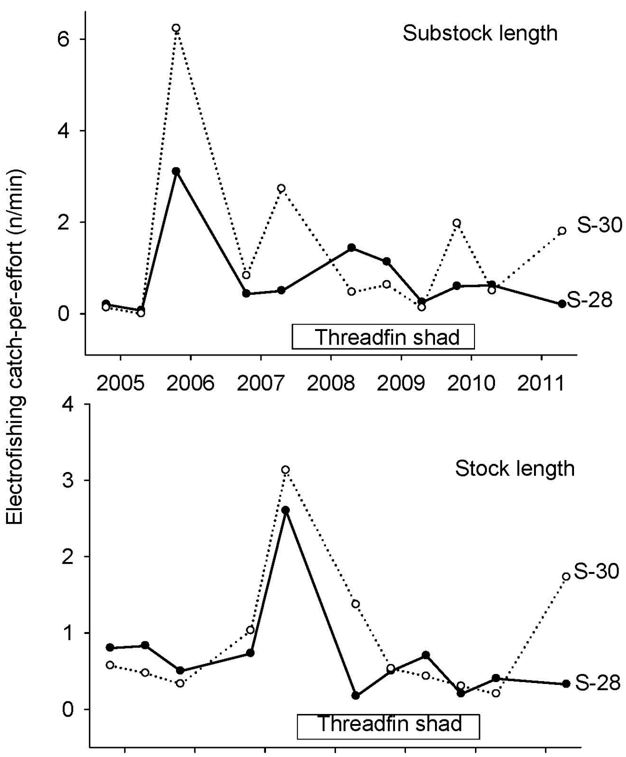

Figure 2. Mean electrofishing catch rates of substock- (top graph) and stock- (bottom graph) length largemouth bass collected over time from S-28 and S-30. The time period for the presence of threadfin shad in each pond is shown in the rectangles.

Discussion

Threadfin shad stocking and presence in these two ponds either caused or were related to three impacts; 1) W_r of bluegill >151 mm TL declined; 2) W_r increased for largemouth bass between 203 and 380 mm TL; 3) lower recruitment of stock- and substock-length largemouth bass occurred which was at least partially responsible for increased proportional size distributions. Our management goal to create largemouth bass fisheries skewed towards larger fish with W_r values over 90 was achieved with threadfin shad introductions.

Lower bluegill W_r during threadfin shad presence were likely not related to competitive feeding and reduced food availability between these two species. Adult threadfin shad are considered primarily detritivores and plantivores (Noble 1981, Davis and

Foltz 1991, DeVries et al. 1991) and adult bluegill feed on macroinverbrates and small fish (Boschung and Mayden 2004). In a review of studies conducted throughout the United States, DeVries and Stein (1990) reported threadfin shad introductions generally had a negative effect on bluegill. Contrary to this result, Haley et al. (2012) found that the presence of threadfin shad had no effect on bluegill population metrics in fertilized ponds or in ponds that were fertilized and bluegill were supplementally fed. Ponds sampled by Haley et al. (2012) were located in the 'black belt region" of southern Alabama where soil fertility is higher than in the region where our ponds were located, which may at least partially explain the disparity between these two studies.

After threadfin shad stocking, W_r of stock- and quality-length largemouth bass increased. However, Wr values did not increase for fish over 380 mm TL when threadfin shad were present in the ponds. Possibly, these larger fish found sufficient larger bluegill to prey upon as gape width, hence prey size, increases with larger fish (Lawrence 1961). Wanjala et al. (1986) noted that intermediate (250–380 mm TL) largemouth bass were more often found offshore feeding on threadfin shad, while larger fish were solitary ambush feeders found closer to shore. If this size-related behavior was exhibited by largemouth bass in our ponds, this may have led to a higher use of bluegill and lower use of threadfin shad by larger fish. During threadfin shad presence, W_r of LMB >380 mm TL was ≥90, but W_r of these fish decreased after the threadfin shad winter kill which suggested loss of these prey fish had a detrimental impact on W_r of these larger predators.

Largemouth bass length distributions fluctuated during the study period. This undoubtedly was due in part to variation in recruitment of stock-length fish, but may have also been influenced by faster growth rates of stock- and quality-length fish during threadfin shad presence as Wr increased during this time period. Production of substock- and stock-fish declined during threadfin shad presence. Reduced recruitment of young largemouth bass has been observed in other ponds stocked with threadfin shad (J. W. Slipke, Midwest Lake Management, Inc., personal communication). Possibly, predation of bluegill by largemouth bass is less in ponds that contain threadfin shad and high bluegill density may inhibit successful largemouth bass spawning (Barwick and Holcomb 1976). Competition for food between age-0 largemouth bass and threadfin shad is unlikely as these species spatially segregate even in small impoundments (DeVries et al. 1991) and largemouth bass tend to spawn earlier than threadfin shad in the southeastern United States (Allen and DeVries 1993). Alternatively, threadfin shad can be indirectly detrimental to young largemouth bass as threadfin shad can reduce young bluegill density and these fish are necessary for young largemouth bass to feed upon and survive (DeVries et al. 1991). Nevertheless, we considered the decrease in production of young largemouth bass as a benefit to our management goal.

In a related study on these same ponds, Sammons and Maceina (2005) found the initial largemouth bass year class stocked into S-28 and S-30 in 2003 consumed 131 and 160 kg ha^{-1} of bluegill during their first year of life. This consumption rate was similar to production estimates of 166 kg ha^{-1} of prey fish in fertilized ponds in North Carolina. Thus, largemouth bass and particularly young fish have the potential to reduce the population of bluegill to densities in which prey is limited at the stocking rates we employed. Interestingly Sammons and Maceina (2005), predicted that "bluegill densities in these ponds may not be great enough to meet predator demand in the future, leading to slower growth, (and) poorer condition …". By fall 2006, this prediction was realized in these ponds, as average W_r values of largemouth bass (203–380 mm TL) declined from 90–105 to 81–86.

Although stocking threadfin shad in private ponds in the southeastern United States is common practice, especially by pond consulting firms, little specific published information currently exists on the impacts, successes, or failures of these stockings. An increasingly common management goal voiced by pond owners is to have quality largemouth bass fisheries skewed towards larger fish. Stocking all-female largemouth bass also has the potential to provide a population containing larger fish as female largemouth bass attain larger sizes than males (Schramm and Willis 2012), but results of this management strategy have not been published. Besides threadfin shad stocking, variable stocking rates and ratios of bluegill to largemouth bass have been used to stock newly-renovated private ponds. We used a stocking ratio of bluegill:largemouth bass of 15:1, and a stocking rate of young largemouth bass of 247 fish ha^{-1}. This stocking rate provided an environment where our management goal was on course for the first 3.5 yrs, then afterwards became unacceptable, which lead us to stock threadfin shad. In some instances today, stocking ratios by private pond consultants of bluegill to largemouth bass have increased to 20:1 to 40:1 in newly-renovated ponds, with fingerling largemouth stocking rates reduced to 75–125 fish ha^{-1} in an attempt to produce "trophy largemouth bass" fisheries (Willis et al. 2010). This ratio is higher than the traditional ratio of 10:1 proposed by Swingle (1951), with a stocking rate of 247 fingerling largemouth bass ha^{-1}, which is the stocking rate adopted by many states agencies (Dauwalter and Jackson 2005). We speculate these higher largemouth bass stocking rates were suitable in the past when harvest was extremely high in ponds.

A drawback of stocking threadfin shad into ponds in our region and in cooler latitudes is the possibility of complete winter kills and loss of these prey fish in ponds. Golden shiners are a common prey fish stocked to augment largemouth bass populations in ponds as supposedly these fish are ideal prey and can reduce largemouth bass recruitment (Wright and Kraft 2012), but little evidence has been published to support the utility of stocking this prey fish. Swingle (1949) in a series of pond experiments found largemouth bass predation eliminated golden shiners in 1–2 yrs after stocking, golden shiners only spawned once during spring, while bluegill continuously spawned during the spring and summer, and golden shiners did not consume largemouth bass eggs or fry. Reiger (1963) found largemouth bass grew faster when golden shiners were stocked into New York, but due to predation, golden shiners were eliminated in some ponds and not sustainable. Hackney (1975) reported golden shiner-largemouth bass stocking combinations were generally more successful and sustainable in northern states, because largemouth bass densities, growth, and sizes were lower compared to southern states. Largemouth bass preferred to consume lake chubsuckers more than bluegill, but largemouth bass growth was similar in ponds that contained both lake chubsuckers and bluegill and ponds only stocked with bluegill (Eberts et al. 1998). In addition, age-0 largemouth bass recruitment was higher in ponds that contained lake chubsucker (Eberts et al. 1998) which we consider a detrimental impact for our management goals. Although anecdotal information exists on stocking alternative prey species other than bluegill in ponds that contain largemouth bass (Wright and Kraft 2012), our literature review indicated little support of these stockings to improve largemouth bass populations.

In conclusion, we predicted (Sammons and Maceina 2005) and then observed that our bluegill:largemouth bass stocking ratio of 15:1 in these two Alabama ponds was too low to meet our long-term management goals. Subsequent stocking of threadfin shad provided for improved quality largemouth bass populations with higher body condition and an increase in length distributions. However, these stockings may sacrifice quality bluegill fisheries as body condition of these fish declined after threadfin shad were stocked. Further research on some of the new and innovative approaches to managing sport fish populations in small ponds including stocking threadfin shad is warranted to refine and improve our findings.

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