Effects of Two Pond Filling Strategies on Production of 75-mm Channel Catfish *Ictalurus Punctatus* in Plastic-Lined Ponds

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TEXAS PARKS & WILDLIFE

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ABSTRACT

Texas Parks and Wildlife Department rears Channel Catfish *Ictalurus punctatus* (CCF) fry to 75-mm fingerlings at the A. E. Wood Fish Hatchery in San Marcos, Texas. These fingerlings are further cultured to larger sizes (230-305 mm) for stocking Texas public waters. Traditionally, fry rearing was accomplished by stocking feed-trained, 5-d-old fry into modified Kansas pond kettles for additional 7-10 d (extended) of feed training before filling ponds with water. During extended feed training in kettles, fry may be subjected to poor water quality because of rainstorms that wash pond bottom sediments into kettles. Sediments in kettles can reduce dissolved oxygen levels and cause high fish mortalities. To avoid fish kills, hatchery employees expose themselves to hazardous weather conditions to shut pond drain valves and fill ponds before sediments can negatively impact the fish. Failing water supplies into pond kettles at night or during inclement weather also has caused fry losses in the past. We conducted this study to determine if extended feed training in pond kettles was a necessary part of the CCF grow-out process or if the risks to fish production and hatchery staff safety could be eliminated. This study compared fish production data over a 3-year period to determine if filling ponds immediately after stocking fry into pond kettles would negatively impact production when compared to the traditional method of filling ponds after extended feed training. In 2008, 2009, and 2010 six 0.4-ha rearing ponds were used for the study each year. Three ponds served as controls where fry were reared using the traditional method and three ponds were filled immediately after fry stocking into pond kettles (treatment). No practical differences were found between treatment and control in terms of fish survival, growth, and feed conversion. Dissolved oxygen concentration, water temperature, and pH (water quality) statistically differed between treatment and control ponds, especially during the first 10-20 d of culture. However, overall water quality was suitable for CCF production in both treatment and control ponds and did not appear to have negatively impacted fish production. Following this study, ponds have been started filling immediately following stocking of CCF fry into pond kettles. This has eliminated the risks to hatchery staff safety and CCF fish production without apparent adverse impact to 75-mm fingerling production.

INTRODUCTION

Prior to 2007, the Texas Parks and Wildlife Department (TPWD) reared Channel Catfish *Ictalurus punctatus* (CCF) fry to 75-mm fingerlings with a three-stage process at the A. E. Wood Fish Hatchery (AEW) in San Marcos, Hays County, Texas. Fry were stocked into feeding trays after hatching and trained to accept commercial diet by feeding them several times daily for 7-10 d (Wyatt et al. 2006). After this initial feed training, fry were transferred into production pond harvest basins (modified Kansas kettles; 20,817 L) at densities of approximately 6 fry/L for 7-10 d of additional feed training. During this phase, cover screens were provided for shade and bird predation prevention. Water flows through pond kettles were maintained at 284 LPM (1.2 h exchange rate). After the additional feed-training period, ponds were gradually filled in 7 d, and 75-mm fingerlings were produced in about 50 d. This standard practice for 75-mm CCF production at AEW was recommended by Wyatt et al. (2006).

The extended (7-10 d) feed training in ponds exposed the production of 75-mm fingerlings and hatchery staff to potential significant risks. During this period, rainstorms compelled staff to fill these fry-rearing ponds prematurely, effectively aborting the extended feed-training phase. Premature pond filling was necessary to prevent sediments and debris at pond bottoms from washing into pond kettles. Sediments and debris, if allowed to wash into kettles, could clog drain screens and reduce water exchange rates and water quality in the kettles; creating conditions that could stress the fry and cause high mortalities. In addition, extended feed training exposed hatchery workers to dangerous conditions such as lightning and slips and fall, because cover screens must be removed and pond valves adjusted to quickly fill ponds immediately after a rainstorm began. Also, water supply to ponds occasionally was interrupted during extended feed training. Loss of fresh water supply into kettles sometimes resulted in high mortality of CCF fry due to dissolved oxygen depletion.

In past years, loss of fry during feed training in kettles has hindered the production capacity of TPWD hatcheries to meet requests for larger fingerlings because the supply of 75-mm fingerlings for further grow-out was adversely impacted. According to hatchery production reports, early pond filling due to rainstorm reduced CCF production in two of the 12 years prior to 2008. We are aware of two similar incidences in the same time frame that were not documented in hatchery production reports. The risk to hatchery staff by managing these ponds during rainstorms also was not documented, but it’s recognized as a significant safety hazard. Moreover, when rainstorms eliminated this feed training period, hatchery staff became anxious because of concerns that less-trained fish would grow slower and have lower survival and poorer feed conversion.

During the 2008 production season, six ponds were used at AEW for 75-mm CCF production. Because of rain, three of these ponds had to be filled almost immediately after fry stocking (early-filled ponds; EF). The fry in the other three ponds, which were stocked the day after the rainstorm, continued to be fed in the pond kettle for 7-10 d (traditionally-filled ponds; TF) before filling. The filling of ponds almost immediately after stocking fry into kettles did not seem to negatively impact production of 75-mm

CCF. This necessary change to the fry culture tactics and the resulting similarity of fish production between EF and TF ponds posed the question of whether the traditional practice of extended feed training in pond kettles and its associated risks to fish production and staff wellbeing were warranted. However, because factors such as stocking density, fry quality, and culture days were not controlled in 2008, a study was conducted for two years comparing the effects of the EF and TF methods on fingerling production before implementing a change to the traditional TPWD CCF culture practices.

In addition, we found that commercial CCF farmers typically do not feed-train CCF fry in ponds using the TF technique. Instead, commercial farmers typically rear CCF by moving fry from hatchery feeding troughs, after 7-10 d of feeding of a starter diet, directly to full rearing ponds (Morrison et al. 1995). If the natural food supply is inadequate, CCF fry readily accept supplemental feed, requiring no extensive feed training (Bonneau et al. 1972). Stocking swim-up fry into properly prepared and full nursery ponds is considered a suitable method for fingerling production (Tidwell et al. 1995). Mischke and Wise (2003) found that CCF fry readily consume large zooplankters such as copepods, cladocerans, and ostracods. Additionally, they recommended CCF fry ponds should be filled and fertilized 2-3 weeks prior to stocking fry to yield the optimal sizes and abundance of zooplankton for the fish (Mischke et al. 2003). Tidwell (1995) found that stocking swim-up CCF fry directly into fertilized rearing ponds resulted in significantly higher survival than fry fed for 7 d before stocking into ponds. However, no significant difference was found in the average weight of the fish at harvest. Lovell (1998) stated that catfish fry stocked directly into large nursery ponds are difficult to effectively feed because they spread out rapidly and are unable to move rapidly to areas where feeds are offered. This report may have driven the AEW staff to use the extended in-kettle feeding phase in CCF fry culture. However, the experience of commercial CCF producers suggested that the extended feed training of CCF fry in pond kettles was unnecessary and supported the need to evaluate the necessity of the TF technique for CCF fry culture. The goal of this study was to determine if the practice of holding fry in kettles for at least 7 d of feed training before filling ponds with water was necessary or if the risks to CCF production and staff safety could be eliminated by excluding this feed-training phase from the 75-mm CCF production protocol. The objective was to determine if the TF method improves pond production performance (survival, growth, and feed conversion ratio; FCR) compared to the ET method in producing 75-mm fingerlings from fry. Since water quality can impact fish production success, select water quality variables also were evaluated.

MATERIALS AND METHODS

This study was performed during 2009 and 2010. Each year, six 0.4-ha (4,731,764 L) production ponds were used for the study. Pond space availability and demand for 75-mm fingerlings dictated a maximum of six ponds each year. Pond bottoms and kettles were swept to remove as much of the sediments as possible before use. All ponds were equipped with insect-mesh-covered drain screens to prevent fry escapement. Three ponds were randomly assigned to the Traditionally-filled (TF) treatment and three to the Early-filled (EF) treatment. In the morning of the fry-stocking day, pond kettles were filled with 500-micron-mesh filtered water, and water flow rates of approximately 284 LPM were maintained through the kettles. These water flows were maintained in TF treatment kettles during the 7-d feed-training period and ceased when TF ponds were started filling.

After initial feed training in indoor trays for 7-10 d, fry were enumerated, harvested, and stocked into pond kettles at a target rate of 287,500 fry/ha for full ponds. The number of fry/kg was determined for each feeding tray by taking three grab samples of fry (~10 g each), weighing and then counting them by hand. The average number of fry/g was calculated by dividing the total number of fry in all three samples by the total weight (Wyatt et al. 2006). Fry were then harvested from feeding trays and weighed, and the total weight was multiplied by the average number of fry/g for that feeding tray to determine the number of fry harvested. As each feeding tray was harvested, the fry were placed in a transport container equipped with diffused oxygen and transported to ponds for stocking into kettles. Fry from each feeding tray were split into two approximately equal portions; half was stocked into a TF pond and the other half into an EF pond to reduce differences in initial fry quality between treatments.

To ensure ponds between treatments were stocked within similar time frames, stocking of fry was alternated between treatments. In 2009, all ponds of both treatments were stocked on the same day. In 2010, two ponds of each treatment were stocked on the same day and one pond of each treatment was stocked the following day. The EF ponds were each started filling with water at approximately 379 LPM immediately after stocking fry into kettles. This water flow rate resulted in the pond becoming full in about 9 d. Filling of TF ponds began after holding fry in the kettles for 7 d; these ponds also were full in about 9 d. Ponds in both treatments were each filled from a valve located above the kettle on the bank of the pond. All TF ponds were provided with protective cover screens laid over the kettles to provide shade and protect fry from bird predation; these screens were removed on the second day after filling of ponds began (day 9). Fry in all study ponds were offered feed four times a day (0700, 1100, 1500 and 1700 hours) beginning on the day of stocking. Fry in TF ponds were fed in the kettles and fry in EF ponds were fed as close to the kettle structure as the rising pond water depth allowed. Fish in all ponds were offered the same amounts of feed based on water temperature and estimated fish biomass; the latter was adjusted as the fish grew (Wyatt et al. 2006). Feeding rates were 6-10% of the estimated biomass depending on fish size and pond water temperature (Wyatt et al. 2006).

Water quality variables (temperature, pH, and dissolved oxygen concentration; DO) were measured with a YSI 600XL multi-probe attached to a model 650 MDS data logger (Yellow Springs Instrument Co., Yellow Springs, Ohio) two times a day (0600 and 1500 hours) in each pond. Individual ponds were flushed with fresh water at 379 LPM and feeding of fry was suspended for the day if morning DO levels fell below 4 mg/L (Wyatt et al. 2006).

Ponds were harvested alternately between treatments to equalize culture days as much as possible. All ponds were harvested within a week of each other. Fish were enumerated at harvest by crowding the fish in the harvest kettle and taking four grab samples. Each grab sample was weighed and the fish counted to determine the number of fish/kg. The four grab samples were averaged to determine the overall number of fish/kg for each pond (Wyatt et al. 2006). Harvest length (mm) was determined by measuring 40 individual fish and determining the average length. Growth rate (mm/d) was determined by subtracting the stocking length from the harvest length and dividing the result by culture days. Survival was determined by dividing the number of fry harvested by the number of fry stocked. Feed conversion ratio was calculated by subtracting the stocking weight from the harvest weight of the fish and dividing the total weight (kg) of feed fed to the fish by the net fish weight gain at harvest (kg).

Treatment data for 2008, 2009, and 2010 were analyzed separately and as pooled data. Fry for these studies were from the same brood fish, and stocking rates and culture days were similar. Therefore, data were pooled to examine potential year effect on production performance. Means of the production variables were compared by *t*-tests with the ANOVA procedure of the SAS Add-In for Microsoft Office, version 4.3 (SAS Institute, Inc., Cary, NC) for each year and pooled years. The same production variables also were analyzed for the effects of year, treatment, and their interaction using the mixed model ANOVA procedure in SAS. We also compared the means and variances of production variables for the four years (2004-2007) of using the TF strategy before this study to the four years (2011-2014) after the EF strategy was adopted. Where differences were significant, multiple comparisons of the effect means were performed with the least squares means test. Water quality data were charted and areas of apparent differences between treatments were further analyzed. These areas for analysis were chosen from where the standard errors of treatment means did not overlap for a period of three or more consecutive days. In general, these areas were considered as periods that most likely corresponded to biologically significant differences between treatments. These biologically significant areas as well as treatment and yearly means of water quality variables also were analyzed with the SAS Add-In. Differences were considered significant at $P \leq 0.05$.

RESULTS

Comparison of Fish Production for Each Year and Pooled Years

Results from *t*-tests of mean production performance variables of EF and TF ponds for each year and pooled years revealed little difference between treatments. In 2010, harvest length was better ($P = 0.0021$) in EF ponds (92 mm) than TF ponds (88 mm). All other variables did not statistically differ between treatments in 2010 or in the other years (Table 1). When all production variables were considered, there appeared to be no significant differences in production that would indicate that filling ponds as soon as fry are stocked (EF ponds) reduces production when compared to ponds that are managed by extended feed training and delayed pond filling (TF ponds).

Analysis of variance revealed no significant difference ($P \geq 0.1267$) in stocking density (fish/ha), weight of feed fed (kg), harvest density (fish/ha), survival, or culture days for the effect of year, treatment, or their interaction (Table 2). The weight of fish harvested (kg) differed ($P = 0.0068$) among years; the weight of fish harvested in 2009

(580 kg) or 2010 (638 kg) was more ($P \leq 0.0327$) than the weight of fish harvested in 2008 (486 kg). However, the treatment effect for harvest weight was not significant ($P = 0.3532$). The length of fish at harvest increased each year ($P = 0.0009$) and was 79.7 mm, 84.3 mm and 90.1 mm in 2008, 2009, and 2010, respectively. However, treatment had no effect ($P = 0.2900$) on harvest length. Feed conversion ratio was different between treatments ($P = 0.0500$), but the difference was small. Feed conversion ratio was better (lower) in EF ponds (0.73) than in TF ponds (0.81). However, FCR (0.83, 0.77, and 0.71 in 2008, 2009, and 2010, respectively) did not significantly differ among years ($P = 0.0570$). The treatment × year interaction effect on FCR also was not significant ($P = 0.3295$). Growth rate was higher in EF ponds (1.49 mm/d) than TF ponds (1.40 mm/d); and though this difference was small (4-mm during a typical grow-out period), it was significant ($P = 0.0404$). Fish production rate was different between treatments ($P = 0.0293$) and higher in EF ponds (31.0 kg/ha/d) than TF ponds (28.3 kg/ha/d). Production rate also was greater ($P = 0.0027$) in both 2009 (31.3 kg/ha/d) and 2010 (31.2 kg/ha/d) than 2008 (26.2 kg/ha/d). The year and treatment interaction effect on production rate was not significant ($P = 0.4607$).

The results of the analysis of variance of the 2008-2010 production data suggest that CCF ponds stocked at similar densities, offered similar amounts of feed, and reared for a similar time period should experience no reduction in overall production performance if the ponds are filled immediately after fry stocking (EF treatments) compared to the TF treatment. Instead, removing the risky TF strategy from the routine culture protocol may offer some slight improvement in growth rate, production rate, and FCR. For almost all production variables, overall variance was similar between the EF and TF treatments ($P \geq 0.4191$). The only significant difference in variance was with FCR ($P = 0.0291$) where the variance for the TF treatment was higher (0.01220) than that of the EF treatment (0.0023). The 5.3 times greater variance in FCR for the TF treatment suggests that the feed-training tactic does not improve attraction of fish to feed and consistency of feed utilization by the fry as intended by this strategy.

Comparison of Fish Production before and after Adoption of the EF Strategy

Few differences were found in CCF production characteristics for the four years prior to the adoption of the EF strategy compared to the four years after the change (Table 3). Stocking densities averaged about 85,948 fry/ha less ($P = 0.0010$) after the EF strategy was implemented. This corresponded to a reduction in fingerling request (demand) and increased confidence in expected production results with the EF strategy, which required less fish for contingency. Fish feeding rates during the typical grow-out period were reduced ($P = 0.0424$) by 304 kg while FCR improved (was lower; $P = 0.0041$) from 1.9 to 1.1 after the EF implementation. The variance of most production variables did not differ between pre- and post-EF implementation. The variance in production declined; was 256 before and 61 after EF implementation ($P = 0.0354$). The variance in harvest length also declined from the pre-EF implementation level; was 35.5 before and 31.3 after the change. Because stocking densities were lower after EF implementation, it is not possible to attribute the improvement in FCR to implementation of the EF strategy. However, there is no evidence that the EF strategy reduced fish production.

Water Quality Differences between Treatments in 2008 -2010

Average morning pond water temperature increased by ≥ 0.6ºC each year ($P < 0.0001$). Morning water temperatures averaged 27.3, 27.9, and 28.9ºC in 2008, 2009, and 2010, respectively. There was no significant effect of treatment on morning pond water temperature ($P = 0.1470$) which averaged 28.1ºC overall. Afternoon pond water temperature differed by year ($P < 0.0001$) and treatment ($P = 0.0004$). Similar increases in afternoon pond water temperatures occurred over the years; these temperatures averaged 29.0, 30.1 and 30.7ºC in 2008, 2009, and 2010, respectively. The effect of treatment on average afternoon pond water temperatures was small (0.5ºC). Afternoon temperatures averaged 30.2ºC in EF ponds and 29.7ºC in TF ponds.

Average morning pond DO averaged 7.5 mg/L and did not significantly differ by treatment ($P = 0.8091$) but did differ by year ($P = 0.0025$); averaging 7.7, 7.5, and 7.3 mg/L in 2008, 2009, and 2010, respectively. Similarly, average afternoon DO (10.1 mg/L) differed by year ($P = 0.0008$) but not by treatment ($P = 0.1177$). Afternoon pond DO averaged 10.5, 10.1, and 9.8 in 2008, 2009, and 2010, respectively and was only significantly different ($P = 0.0002$) between 2008 and 2010. These decreases in morning and afternoon DO levels over the years were likely due to the increases in pond temperatures over the same period.

Average morning pond water pH (8.5) differed by year ($P < 0.0001$), treatment ($P = 0.0064$), and their interaction ($P = 0.0071$). Morning pond water pH decreased slightly each year averaging 8.6 in 2008 and 8.3 in 2010. The difference in pH between EF and TF was small; pH averaged 8.5 and 8.4 for EF and TF, respectively. Average afternoon pond water pH (8.7) differed by year ($P < 0.0001$), treatment ($P = 0.0003$), and their interaction ($P = 0.0358$). Afternoon pond water pH decreased slightly each year and averaged 8.9 in 2008 and 8.6 in 2010.

The observed differences in average pond DO, temperature, and pH between EF and TF treatments apparently were largely caused by differences that occurred during the first 10-20 d of pond culture (Figures 1, 2, and 3). The EF ponds warmed faster, and had higher DO and pH as the pond bottoms flooded. Conversely, the TF ponds experienced cooler water temperatures and lower pH and DO levels while fry were held in the pond kettles, with flow-through water, for extended feed training.

Morning and afternoon pH values were different between treatments during the first 20 d ($P < 0.0001$ and $P = 0.0001$, respectively), and the differences averaged 0.30 and 0.32, respectively. The pH ranges of EF (7.1-9.5) and TF (7.3-9.1) ponds were mostly within the range (6.0 – 9.0) considered optimal for CCF fry and fingerling culture, and all pH values were within the range (5 – 10) considered tolerable by CCF (Wyatt et al. 2006).

During the first 10 d of culture, the difference between morning and afternoon pond water temperatures was significant between treatments ($P < 0.0001$). Morning pond water temperatures averaged 26.5ºC in EF ponds and 25.8ºC in TF ponds. Afternoon pond water temperatures averaged 29.8ºC in EF ponds and 27.5ºC in TF ponds.

However, average water temperatures for both treatments and for both morning and afternoon were near the range (27- 29ºC) considered optimal for CCF culture (Wyatt et al. 2006). During the first 10 d of culture, the range of pond water temperatures was 22.6-34.9ºC in EF ponds and 24.1-32.4ºC in TF ponds. Therefore, without refuge CCF fry could be exposed to more extreme water temperatures in EF ponds than in TF ponds. Feed consumption and growth of CCF increase with temperature to maximum rates at 32ºC (Lovell 1998). Therefore, it is possible that these early higher pond water temperatures in EF ponds contributed to the improvement in production performance (i.e., growth rate, production rate, and FCR) observed in these ponds.

Both morning and afternoon average DO values were significantly different between EF and TF ponds ($P = 0.0002$ and $P < 0.0001$, respectively). Average morning DO was 8.4 mg/L in EF ponds and 8.0 mg/L in TF ponds, whereas the afternoon average was 11.2 mg/L in EF ponds and 8.7 mg/L in TF ponds. These averages fall well within the optimal range (5-15 mg/L) for CCF grow-out (Wyatt et al. 2006). Neither treatment was associated with a DO value of less than 2.0 mg/L, which is below the tolerable level for CCF survival. The minimum DO observed in EF ponds was 3.8 and levels below 5.0 were only observed three times during the three years of culture. Dissolved oxygen in TF ponds never fell below 5.0 mg/L on any day during the three years, suggesting that fresh water inflow rates were adequate to maintain appropriate levels of DO for the densities of fish held in pond kettles during extended feed training. Both treatments appear to have provided adequate levels of DO for CCF culture.

DISCUSSION

The purpose of this study was to determine if the risks associated with holding CCF fry in pond kettles for a 7- to 10-d feed training before pond filling could be eliminated without adverse impact on the production of 75-mm fingerings. Three years of side-by-side comparisons of the two culture techniques and pre- and post-EF implementation comparisons strongly suggest that the risks to production and staff safety of using the TF strategy is not warranted. Compared to the EF strategy, the TF strategy does not seem to improve production of 75-mm fingerlings. By replacing the TF with the EF strategy, 75-mm fingerling production capacity of ponds is maintained while the risks to staff safety and fingerling production are eliminated. Further, the anxiety associated with the potential risk of losing fingerling production through fry mortality during the extended feed-training period also is eliminated.

The EF strategy for CCF fry rearing in ponds was implemented in 2011 with no apparent detriment to 75-mm fingerling production in subsequent years. Instead, grow-out of these fingerlings has become more reliable and efficient. Thus far, there have been no catastrophic losses of fry that would create shortages of 75-mm fingerlings for grow-out to larger sizes. Additionally, there appears to be improvements in some CCF fingerling production metrics with the EF strategy. However, the reduced average fry stocking density and the slight increase in pond water temperatures during the first 10 d of culture during this period may have contributed to the observed improvements in fingerling production. Based on the findings of this study and evaluation of production data since implementation of the EF strategy in CCF fry rearing ponds, we recommend that ponds should begin filling immediately after stocking fry in pond kettles. The TPWD CCF culture guidelines (Wyatt et al. 2006) should be updated to reflect this change to the 75-mm CCF production procedures.

While the change to the TPWD 75-mm CCF production strategy is apparently beneficial in terms of staff safety without a detriment to production, we would like to point out that our water quality data did indicate some potential problems that might not make this EF strategy applicable to all aquaculture situations. As EF ponds begin to fill, the initial thin layers of water covering pond bottoms are vulnerable to ambient weather and environmental conditions (e.g., warmer plastic liners) which could cause higher extremes of temperature, DO, or pH. This situation is more likely if pond filling takes several days or ambient temperatures are more extreme than those observed in this study. In addition, our fry were not stocked into full ponds, therefore, in both EF and TF ponds there was some level of fry concentration around feeding locations, albeit, the fry in EF ponds were likely less concentrated because the ponds were filled relatively quickly. Applying these findings to ponds which are completely filled prior to fry stocking might not produce similar results because fry may disperse over a larger area more quickly and be more difficult to attract to feed (Lovell 1998).

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TABLE 1.—Mean ± SD and *P* values for comparisons (*t*-test) of three years of production data for fingerling Channel Catfish *Ictalurus punctatus* reared in ponds where 3 ponds each year were filled immediately after fry stocking into pond harvest basins (Early filled) or filled after 7 d of feed training in harvest basins (Traditionally filled) at the A. E. Wood Fish Hatchery.

Production variable	Early-filled	Traditionally-filled	*P*-value
	2008		
Stocking density (fish/ha)	289,936 ±16,615.5	313,182 ±32,721.6	0.3342
Feed fed (kg)	371 ± 49.9	425 ± 106.3	0.4729
Harvest density (fish/ha)	299,042 ± 44,887.4	289,024 ± 24,600.4	0.7517
Weight harvested (kg)	494 ± 50.7	477 ± 71.0	0.7592
Harvest length (mm)	81 ± 1.8	78 ± 3.5	0.2901
Culture days	43 ± 3.5	49 ± 4.7	0.1692
Growth rate (mm/d)	1.5 ± 0.15	1.3 ± 0.06	0.0581
Production rate (kg/ha/d)	28 ± 1.1	24 ± 2.3	0.0512
Feed conversion ratio	0.8 ± 0.038	0.9 ± 0.143	0.1827
Survival	1.04 ± 0.210	0.93 ± 0.152	0.5142
	2009		
Stocking density (fish/ha)	296,083 ± 11,114.6	295,559 ± 2,570.4	0.9404
Feed fed (kg)	440 ± 68.9	444 ± 69.5	0.9470
Harvest density (fish/ha)	285,885 ± 14,102.8	261,056 ± 29,975.6	0.2640
Weight harvested (kg)	610 ± 124.3	550 ± 56.9	0.4892
Harvest length (mm)	84 ± 6.1	85 ± 4.5	0.7212
Culture days	46 ± 3.8	46 ± 3.8	1.0000
Growth rate (mm/d)	1.4 ± 0.03	1.4 ± 0.06	0.3573
Production rate (kg/ha/d)	33 ± 3.9	30 ± 0.6	0.2443
Feed conversion ratio	0.7 ± 0.03	0.8 ± 0.04	0.0563
Survival	0.96 ± 0.016	0.88 ± 0.108	0.3205
	2010		
Stocking density (fish/ha)	302,038 ± 23,293.4	289,311 ± 1,065.0	0.4439
Feed fed (kg)	453 ± 41.3	446.7 ± 42.8	0.8626
Harvest density (fish/ha)	279,797 ± 27,973.2	278,630 ± 2,842.7	0.9491
Weight harvested (kg)	646 ± 18.7	631 ± 28.5	0.4658
Harvest length (mm)	92 ± 0.4	88 ± 1.0	0.0021
Culture days	50 ± 3.5	50 ± 3.6	1.0000
Growth rate (mm/d)	1.6 ± 0.10	1.5 ± 0.09	0.3389
Production rate (kg/ha/d)	32 ± 2.2	31 ± 2.1	0.6740
Feed conversion ratio	0.7 ± 0.07	0.7 ± 0.05	0.9015
Survival	0.93 ± 0.033	0.96 ± 0.008	0.1276
	2008 - 2010 combined		
Stocking density (fish/ha)	296,019 ± 16,217.6	299,351± 19,609.6	0.6997
Feed fed (kg)	421 ± 60.8	438 ± 67.8	0.5808
Harvest density (fish/ha)	288,241 ± 28,664.2	276,237 ± 22,974.5	0.3415
Weight harvested (kg)	583 ± 96.7	553 ± 81.7	0.4758
Harvest length (mm)	86 ± 6.0	84 ± 5.2	0.4996
Culture days	46 ± 4.4	48 ± 4.0	0.3528
Growth rate (mm/d)	1.5 ± 0.12	1.4 ± 0.09	0.0760
Production rate (kg/ha/d)	31 ± 3.1	28 ± 3.5	0.1086
Feed conversion ratio	0.7 ± 0.05	0.8 ± 0.11	0.0889
Survival	0.97 ± 0.118	0.93 ± 0.008	0.3421

TABLE 2.— *P*-values of analysis of variance for the effects of treatment, year, and treatment × year interaction on production variables for fingerling Channel Catfish *Ictalurus punctatus* reared in ponds in 2008-2010 at the A. E. Wood Fish Hatchery. Treatments were ponds filled immediately after fry stocking (Early-filled) and ponds filled after fry were feed trained for 7 d in harvest basins (Traditionally-filled).

Production variable	Treatment	Year	Treatment × Year
Stocking density (fish/ha)	0.7069	0.8209	0.2640
Feed fed (kg)	0.5978	0.3799	0.7157
Harvest density (fish/ha)	0.3712	0.4327	0.7567
Weight harvested (kg)	0.3532	0.0068	0.8133
Harvest length (mm)	0.2900	0.0009	0.3347
Culture days	0.3161	0.1267	0.3659
Growth rate (mm/d)	0.0404	0.1637	0.0591
Production rate (kg/ha/d)	0.0293	0.0027	0.4607
Feed conversion ratio	0.0500	0.0520	0.3295
Survival	0.3743	0.6559	0.5309

TABLE 3.—Mean ± SD and *P* values for comparisons (*t*-test) of production variables for fingerling Channel Catfish *Ictalurus punctatus* reared in ponds for four years (2004-2007) when extended feeding in pond harvest basins was the accepted practice (before) and after the practice was abandoned (2011-2014) at the A. E. Wood Fish Hatchery.

Production variable	Before (2004 - 2007)	After (2011 - 2014)	*P*-value
Number of ponds	28	22	.
Stocking density (fish/ha)	387,300 ± 16,292.9	301,352 ± 18,380.8	0.0010
Feed fed (kg)	866 ± 98.5	562 ± 107.1	0.0424
Harvest density (fish/ha)	341,151 ± 17,318.8	292,487 ± 19,538.3	0.0685
Weight harvested (kg)	528 ± 42.1	544 ± 47.4	0.7884
Harvest length (mm)	82 ± 2.5	84 ± 2.8	0.5531
Culture days	43 ± 1.5	45 ± 1.7	0.4001
Growth rate (mm/d)	1.5 ± 0.05	1.50 ± 0.05	0.7345
Production rate (kg/ha/d)	36 ± 1.6	31 ± 1.8	0.0835
Feed conversion ratio	1.9 ± 0.18	1.1 ± 0.20	0.0041
Survival	0.89 ± 0.033	0.96 ± 0.037	0.1390

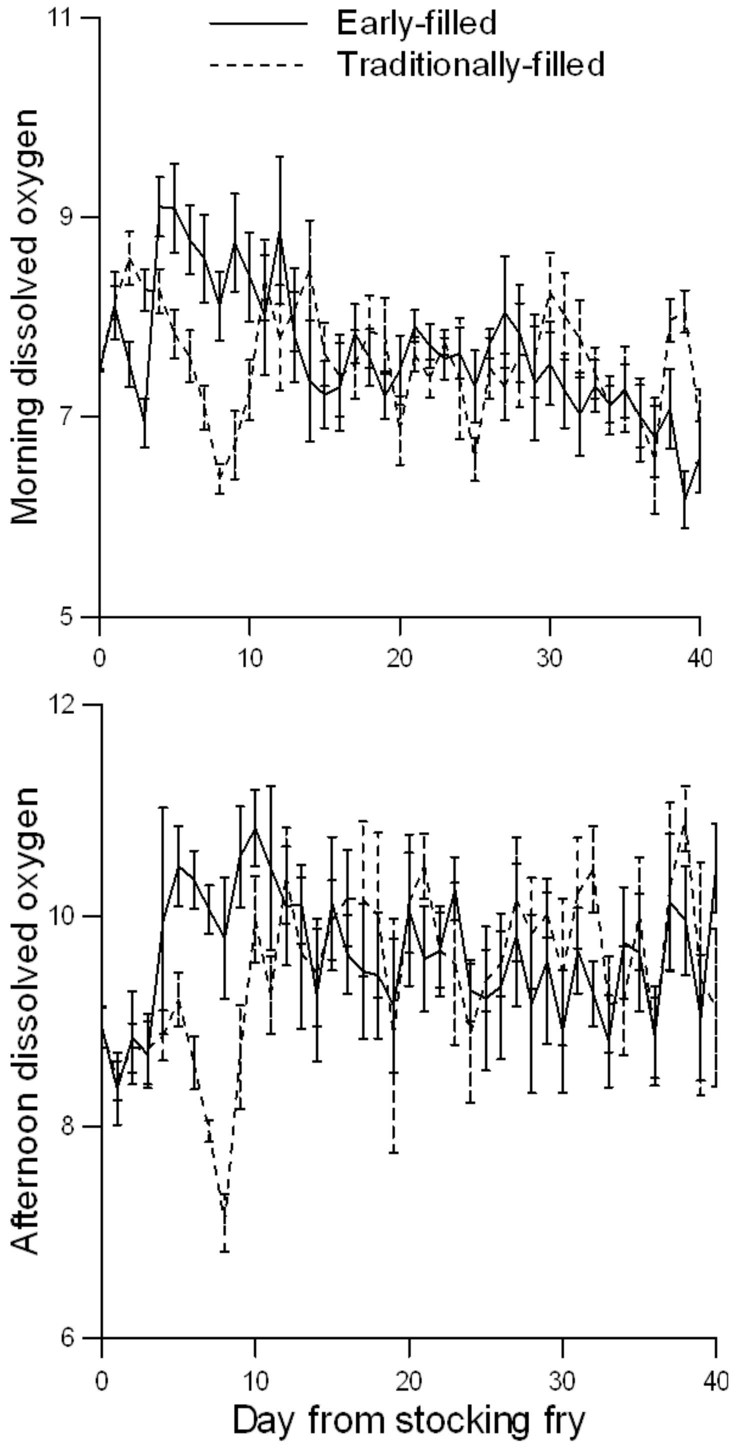

FIGURE 1.—Morning and afternoon dissolved oxygen levels (mg/L) in Channel Catfish *Ictalurus punctatus* fry rearing ponds in 2008-2010 at the A. E. Wood Fish Hatchery. Early-filled ponds were filled immediately after fry stocking. Traditionally-filled ponds were filled after fry were feed trained for 7 d in pond harvest basins. Bars are standard errors.

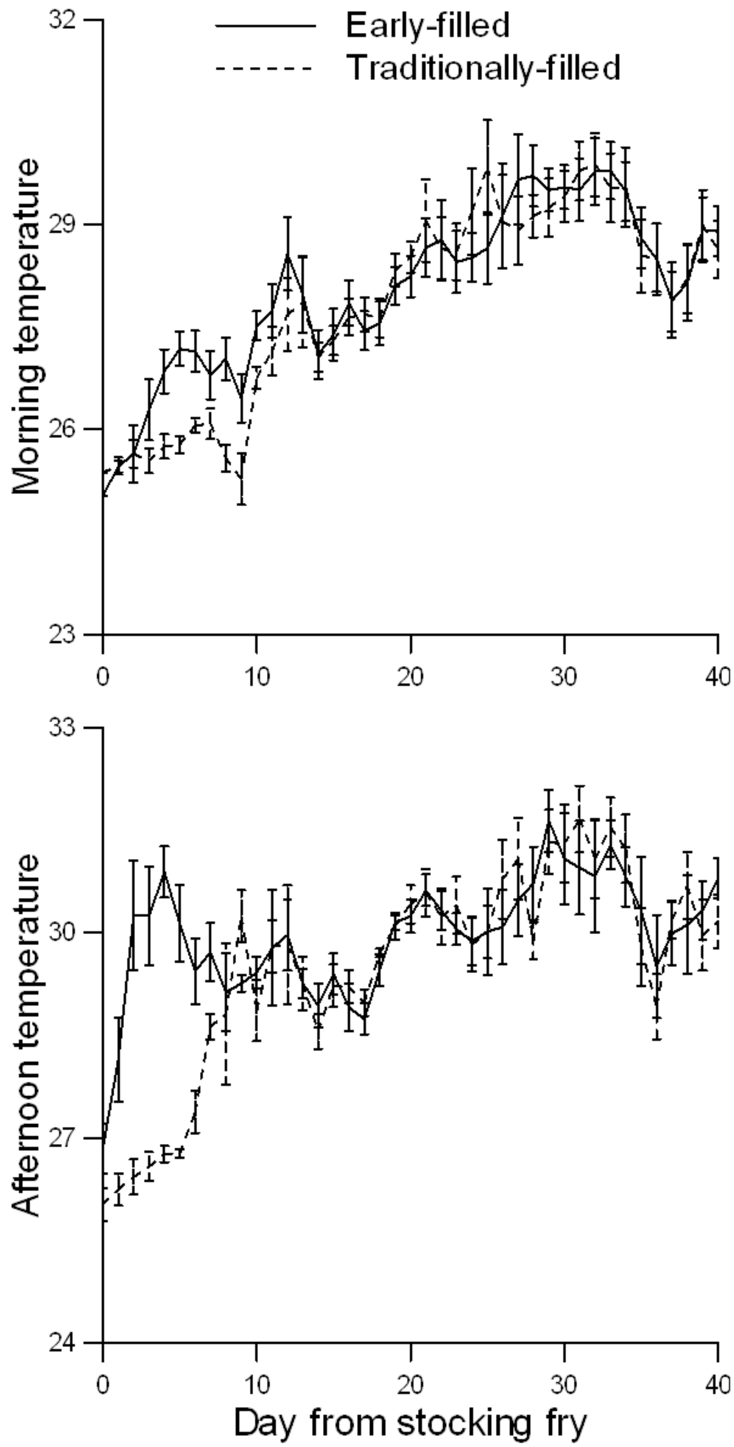

FIGURE 2. —Morning and afternoon temperatures (ºC) in Channel Catfish *Ictalurus punctatus* fry rearing ponds in 2008-2010 at the A. E. Wood Fish Hatchery. Early-filled ponds were filled immediately after fry stocking. Traditionally-filled ponds were filled after fry were feed trained for 7 d in pond harvest basins. Bars are standard errors.

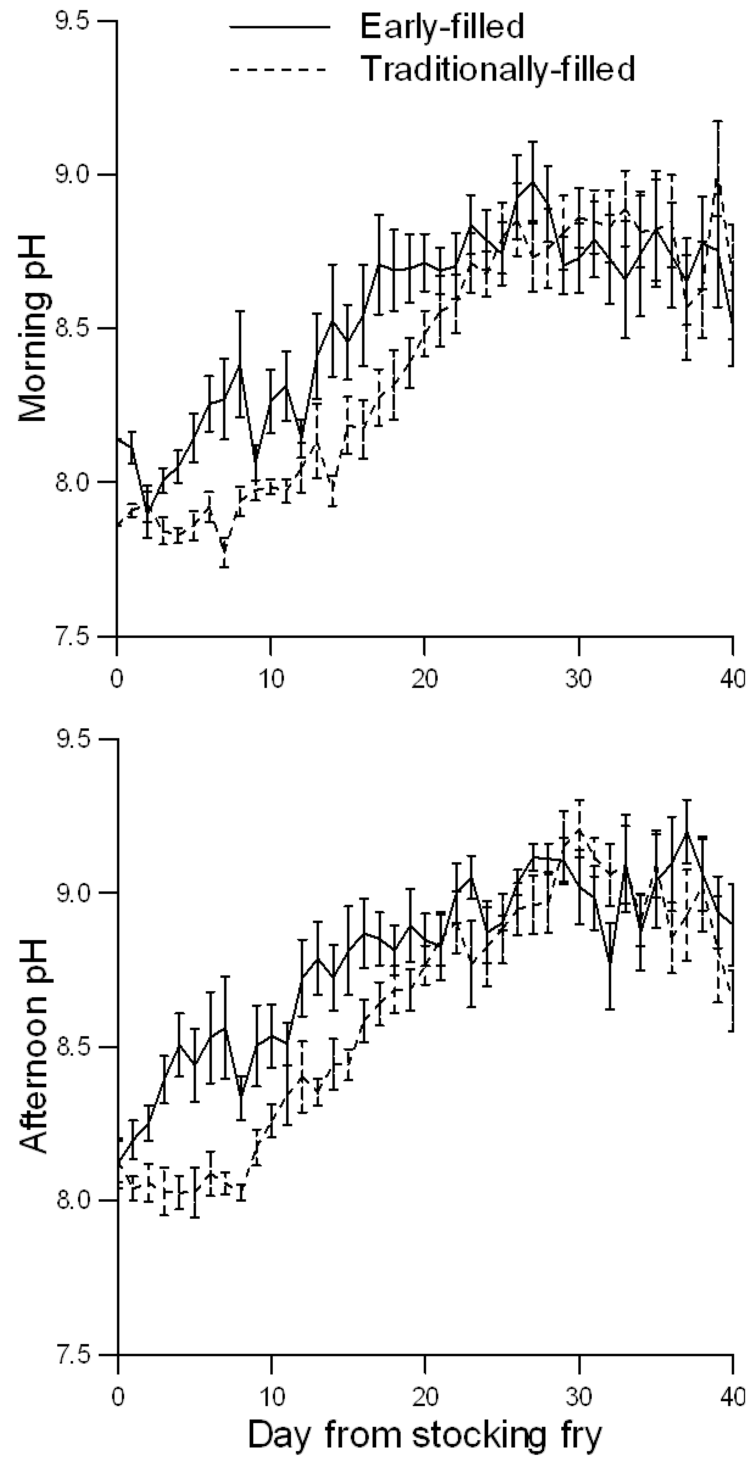

FIGURE 3. —Morning and afternoon pH in Channel Catfish *Ictalurus punctatus* fry rearing ponds in 2008-2010 at the A. E. Wood Fish Hatchery. Early-filled ponds were filled immediately after fry stocking. Traditionally-filled ponds were filled after fry were feed trained for 7 d in pond harvest basins. Bars are standard errors.

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