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ABSTRACT

Feed rings are used at some fish hatcheries to reduce feed waste, maintain water quality, and improve growth and feed conversion ratios (FCR) in channel catfish *Ictalurus punctatus* fingerling rearing ponds. However, the efficacy of feed rings in achieving these fish production goals appears undetermined. Similarly, the extent of feed ring use in fish production among warmwater fish hatcheries in the USA is unknown. We determined the prevalence of feed ring use among state fish hatcheries in the southeastern USA using a survey and evaluated the effect of a feed ring, measuring 5.8 m × 5.8 m, on advanced (229-305 mm) channel catfish production variables (harvest length, length uniformity, harvest weight, production, percent return, and FCR) in plastic-lined ponds from June to October 2007. Six ponds for growing advanced channel catfish (Imperial strain) fingerlings from 76-mm fish were used for the study: three ponds received a feed ring each (treatment) and three received no feed rings (control). Channel catfish from treatment ponds were significantly shorter and weighed less than those from control ponds. However, catfish from treatment ponds were significantly more uniform in total length. Production, percent return, and FCR did not significantly differ between groups. Water temperature, dissolved oxygen, and pH were similar between treatment and control ponds and did not seem to have affected catfish production. These results indicated that the feed ring used in this study did not enhance catfish growth or feed conversion ratio. The survey revealed that while majority (87% of respondents) of the state warmwater fish hatcheries in the southeastern USA produce 152-mm or larger channel catfish, few (14%) use feed rings in the production of advanced channel catfish fingerlings in ponds. However, our inability to include in the survey all 54 state warmwater fish hatcheries in the 15 states which comprise the Southeastern Division of the American Fisheries Society makes our results tentative.

INTRODUCTION

Texas Parks and Wildlife Department (TPWD) Inland Fisheries Hatchery Branch produces over 288,000 advanced (229 and 305 mm) channel catfish *Ictalurus punctatus* fingerlings annually. These fingerlings are primarily stocked into urban impoundments as part of the department's program of providing convenient fishing opportunities for the Texas growing urban population. The pond production season for the 229-mm catfish program expands approximately 100 d, culminating in stocking the fish into urban lakes beginning in early October. Some of these 229-mm catfish are over-wintered to produce larger fingerlings for the 305-mm catfish program, which begins in March and ends in November. These defined time periods require efficient and timely production of fingerlings for success of the programs.

Successful production of desired-size channel catfish at the right time requires adequate feeding of the fish to promote growth while maintaining good water quality to support healthy fish. Most catfish producers prefer to feed the fish floating feed (Li and Robinson 2008) so that they can observe feeding behavior to assess the general health of the fish and not necessarily because there is a growth advantage to feeding catfish pelleted feed (Mgbenka and Lovell 1984). However, feeding catfish floating feed in ponds can result in waste of feed due to wind action that carries the feed to pond banks where it become unavailable to the fish. Further, the uneaten feed can contribute to poor water quality that adversely affects fish growth and feed conversion ratio (FCR) (Wurts 2001). Because the cost of feed can account for 44-50% of the cost of producing channel catfish in ponds (Engle and Stone 2002; Wurts 2001) and unconsumed feed can cause water quality deterioration to adversely affect fish production, avoiding waste is necessary to achieving efficient FCR and profitability of commercial farms (Engle and Stone 2002; Wurts 2001) or efficient programs of state and federal agencies.

Feed rings are enclosures that float at the water surface to hold floating feeds to prevent or at least reduce waste. Use of floating feed rings has been recommended for commercial production of hybrid striped bass (D'Abramo and Frinsko 2008) and cage culture of a variety of fishes (Lazur 2000). In addition, feed rings have been used in studies that evaluated different feeding practices for pond-reared rainbow trout (Tidwell et al. 1991), feed types in pond-raised sunshine bass (Pine et al. 2008) as well as in determining the effects of feed types and feed shelters on catfish production (Mgbenka and Lovell 1984; Collier and Schwedler 1990; Watanabe et al. 1990; Kelly and Kohler 1996; Torrans and Lowell 2001). Feed rings also are used in pond culture to mitigate dispersion of feed by wind while training fry to consume commercial feed, improve swim bladder inflation in susceptible fish species, or provide medicated feeds for treatment of diseases (Barrows et al. 1988; Johnson and Smith 1994).

The use of feed rings in the culture of advanced channel catfish in ponds may be beneficial. The perceived benefits of feed ring use include encouragement of aggressive feeding behavior in fish to enhance growth, increased exposure time of the feed to fish resulting in improved probability of feed ingestion by the fish, and reduced feed waste by minimizing quantities of feed blown by wind onto pond banks where they become unavailable to fish. Consequently, feeding catfish using feed rings may result in better FCR. Feed rings may also promote better water quality conditions because feed waste is minimal. Although feed rings are used at some fish production facilities, including four of the five TPWD hatcheries that produce advanced channel catfish, we are unaware of any study that demonstrates the perceived benefits of feed rings in the culture of advanced (229-305 mm) channel catfish fingerlings in ponds. We conducted this study to determine the effects of feed ring on the culture of advanced (229 mm) catfish fingerlings. The objectives were to determine if the use of a 5.8- × 5.8-m feed ring enhances FCR, water quality, and ultimately growth of channel catfish, thus resulting in a more timely and efficient production of the target size fish. Additionally, use and perceived benefits of feed rings among state warmwater fish hatcheries in the southeastern USA were investigated.

MATERIALS AND METHODS

This study consisted of a survey of southeastern state warmwater fish hatcheries and a field experiment conducted at the Possum Kingdom State Fish Hatchery, Palo Pinto County, Texas. This hatchery is located in the north-central part of the state where prevailing southwesterly wind speeds of 5-20 miles per hour are common throughout most of the summer. To gather information on the prevalence of use of feed rings among US state warmwater fish hatcheries, we conducted a survey through the Aquaculture Technical Committee of the Southern Division of the American Fisheries Society's "Listserve." The survey questionnaire was distributed via e-mail to hatchery managers in the southeastern states in July 2008 with a one-month time frame to return responses. Respondents answered five questions on the culture of advanced catfish fingerlings, feeding methods, and use of feed rings for production of advanced fingerlings. The specific questions were:

1) Does your hatchery produce 152-mm or larger catfish fingerlings?
2) When feeding fish, is the feed dispersed around the pond or concentrated in a defined area?
3) Does your hatchery use floating feed rings to concentrate feeds in advanced channel catfish fingerlings production ponds?
4) Does your hatchery use floating feed rings in producing advanced fingerlings other than catfish in ponds?
5) If your hatchery uses floating feed rings in feeding catfish or other fishes, what do you believe are the benefits?

The field study was conducted from June to October 2007. Six production ponds, averaging 0.3 (± 0.03) ha, were randomly assigned to treatment and control groups, each with three replicates. Each treatment pond was provided with one 5.8- × 5.8-m feed ring placed in the center of the deepest (2 m) part of the pond, approximately 3 m from the harvest kettle. This location allowed successful placement of feed into the feed rings. Feed rings were secured with ropes tied to pegs in the levees. The feed ring occupied about 1% of the total surface area of the pond. Control ponds received no feed rings. Feed rings were constructed using 10-cm schedule 40 polyvinyl chloride (PVC) pipe and fittings.

Channel catfish fingerlings averaging 79.9 mm (range = 52-96 mm) total length were received from the A. E. Wood Fish Hatchery in San Marcos, Texas on two fish delivery units. To ensure all ponds received fish of similar condition, average length, and length variability, the fish on the two fish delivery units were mixed before stocking into ponds at rates of 28,365-29,015 fish/ha. Fingerlings were fed according to a predetermined feed schedule that was based on a target FCR of 1.5 for normal culture conditions. Total feed for each pond was determined by multiplying the target FCR by the total weigh of 229-mm fish expected from each pond minus the initial stocking weight. The expected total weight was based on historical production data (percent return) and length-weight tables in Piper et al. (1983). Once the quantity of feed for each pond was determined, the feed sizes and rations were established from a hatchery feeding protocol (Wyatt et al. 2006). All pond feeding regimes were similar in terms of feed sizes and percent body weight of fish. Feed sizes varied from a number-3 high protein (50%) sinking pellet initially to 1.5-, 3.5- and 5.5-mm floating pellets (35% protein) (Silver Cup Feeds, Murray, Utah) as the fish grew. The feed was offered to the fish twice daily at 0600 and 1500 hours. Fish in control ponds were fed by dispersing the feed onto the pond water surface along the entire length of the upwind side of the pond and allowing the wind to carry it across the pond. For feed-ring ponds the feed was thrown onto the water surface inside the feed rings.

Ponds were managed for water quality according to TPWD culture guidelines (Wyatt et al. 2006), and all ponds were similarly treated. Dissolved oxygen (DO), temperature, and pH of pond waters were monitored twice daily using a YSI 650 MDS handheld meter fitted with a YSI 600 XL multiprobe sensor (Yellow Springs Instruments, Yellow Springs, Ohio). Ponds were provided a constant water exchange at approximately 189 L/min and low-pressure air to maintain water quality.

The study ended with harvest of the fish that began when the average length of fingerlings was approximately 229 mm. Because of the fish delivery schedule, all six ponds could not be harvested simultaneously. To equalize the production days for the treatment and control groups, fish harvest was synchronized by harvesting one pond containing the largest fish from each group on the same day. Pond harvesting was completed in 23 d. For each pond, all the fish as well as four samples of 50 fish each were weighed and 200 individual length measurements were taken. These data were used to calculate average total length, harvest weight (fish/kg), and production (kg/ha). Percent return and FCR were also calculated for each pond.

The fish production data (total length, harvest weight, production, percent return, and FCR) were analyzed using the two sample *t*-test procedure in SAS (SAS Institute 2002), whereas the water quality data were analyzed by repeated measures analysis of variance (split plot design) using the general linear model (GLM) procedure in SAS. Equality of variances was used to test fish length uniformity between treatment and control. Statistical significance level was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

A total of 16 fish hatcheries (40% of surveyed hatcheries) responded to the survey, and approximately 87% of respondents produce 152-mm or larger channel catfish. Among respondents that produce advanced channel catfish, 79% broadcast the feed onto the pond water surface and 21% concentrate the feed in defined areas of the pond. Fourteen percent of the hatcheries that produce advanced channel catfish use feed rings. Increased feeding opportunity for fish and less waste of floating feed were cited the most as justification for using feed rings. These results suggest few state warmwater fish hatcheries in the southeastern USA use feed rings in the production of advanced channel catfish fingerlings in ponds. However, our inability to include in the survey all 54 state warmwater fish hatcheries in the 15 states which comprise the Southeastern Division of the American Fisheries Society makes our conclusion tentative.

The field study lasted an average of 103 (90 –112) d which was similar to the typical time frame for production of 229-mm channel catfish at the Possum Kingdom State Fish Hatchery. There was no treatment effect on water temperature, pH, or DO over the course of the study; however, each of these variables differed significantly over time within each group (Figure 1). The low DO concentration (3.3 mg/L) in feed-ring ponds on September 25 was caused by a single pond that was being drained to harvest the fish. We believe this single event was not biologically significant due to its short duration (Wyatt et al. 2006), and we did not observe adverse effects (e.g., lethargy, mortality) on the fish. Overall, water quality was suitable for channel catfish culture (Torrans 2008; Wyatt et al. 2006) and likely had no effect on the fish production results. Feed waste that could have contributed to water quality deterioration was either similar between treatment and control or the water exchanges negated any potential adverse effects of differential feed waste on water quality.

At the time of stocking fish into ponds, the mean total length, length variability, and stocking rate did not significantly differ between treatment and control ponds. At the end of the study mean total length and harvest weight (fish/kg) were significantly greater in control ponds than in feed-ring ponds (Table 1). This observation is consistent with previous results that suggested that spreading feed around the pond perimeter, instead of concentrating it in a small area, encourages maximum growth in channel catfish (Randolph and Clemens 1976). The FCR was 1.2 for the control and 1.4 for feed-ring ponds. These FCR values are similar to values that Cole and Boyd (1989) and Li et al. (1998) indicated represented efficient feed conversion in channel catfish. Fish production and FCR were 19 and 16%, respectively better in the control than in feed-ring ponds, yet the differences were not statistically significant. The differences in FCR and the other production variables may be due to the difference in the quantities of feed consumed by both groups of fish (Andrews and Page 1975; Li et al. 1998). Ponds with similar densities of fish received the same amount of feed, but we often observed leftover, uneaten feed in feed-ring ponds and rarely in control ponds. The apparent lack of aggressive feeding by fish in feed-ring ponds is difficult to explain, but may have resulted from concentrating the feed in a small area in the deeper end of the pond. Conversely, fish in control ponds fed more aggressively and appeared to have consumed relatively more feed or used the feed more efficiently than fish in feed-ring ponds as suggested by the production variables. Percent return did not significantly differ between treatment and control, suggesting that the better production results for the control was due to better growth and not differential survival of the fish.

The length frequency distributions (Figure 2) also suggested that dispersing feed onto pond water surfaces promoted better growth in advanced channel catfish than concentrating the feed inside feed rings. Approximately 35% of the fish fed in feed rings were smaller than the 229-mm target size compared to 21% for the control ponds. Over 22% of the fish from the control ponds were 300 mm or larger whereas 8% of the fish from feed-ring ponds were 300 mm or larger. These results suggest channel catfish produced from feed-ring ponds were of less quality (i.e., fewer reached the 229-mm target size) and the resulting smaller fish would require more time and manpower for additional rearing before they could be used in the TPWD 305-mm catfish program.

The standard deviations of the total lengths were 37.8 and 43.2 mm for the feed-ring and control ponds, respectively and significantly different (Table 1), indicating that the fish from the feed-ring ponds were more uniform in size. These results appear to be unsupportive of the recommendation that feed should be dispersed around the pond perimeter, instead of a small area, to discourage feeding hierarchy and achieve size uniformity in channel catfish (Randolph and Clemens 1976). Unlike Randolph and Clemens (1976), the present study used fish of similar sizes and that may explain why concentrating the feed in feed-rings did not adversely affect size uniformity in the advanced catfish fingerlings.

Both control and feed-ring ponds produced fish of the desired minimum average size. However, broadcasting the feed over a large area of the pond water surface produced bigger fish with high size variability whereas presenting the feed inside feed rings produce relatively smaller fish of uniform size. Anecdotally, it took about 5 and 15 min to weigh and apply feed into a feed ring and around a pond, respectively, which should translate into higher input (labor) cost for the technique used in the control ponds of this study. Obviously, both methods of feed delivery appear to have advantages and disadvantages; which one to use would depend on catfish production goals. Because the goal of most culturists is to achieve maximum efficiency or profitability in the production of catfish (Boyd and Tucker 1998), developing a feeding protocol that maximizes feed conversion efficiency, fish growth, and size uniformity while minimizing production cost would be beneficial. Most respondents of our survey believe, perhaps through personal experiences, that feed rings can minimize feed waste and improve catfish production efficiency. Results of this study did not seem to support this belief and that may be due to the small size of the feed ring we used. Future research should investigate large feed rings in areas that experience frequent windy weather.

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Table 1. – Production summary for advanced channel catfish fingerlings reared in plastic-lined ponds and fed using either feed rings or no feed rings at the Possum Kingdom State Fish Hatchery for 103 d from June to October 2007. Within columns, means or standard deviations (SD) followed by different letters are significantly different ($P \leq 0.05$).

Pond	Harvest date	Total length (mm)	Production (kg/ha)	Harvest weight (fish/kg)	Percent return	FCR
			Control			
35	10/17	285.4	3,937.4	4.82	65.5	1.0
38	10/3	265.3	2,970.3	5.80	59.7	1.3
40	9/25	240.0	3,155.2	6.98	77.1	1.1
Mean		263.9 z	3,354.3 z	5.9 z	67.5 z	1.2 z
SD		43.2 z	513.4	1.1	8.9	0.2
			Feed ring			
36	10/17	262.4	2,884.3	5.85	58.2	1.4
39	10/3	243.5	2,539.3	6.50	57.6	1.6
42	9/26	230.5	2,798.8	7.86	75.1	1.4
Mean		245.5 y	2,710.8 z	6.7 y	63.6 z	1.4 z
SD		37.8 y	172.5	1.3	9.9	0.1

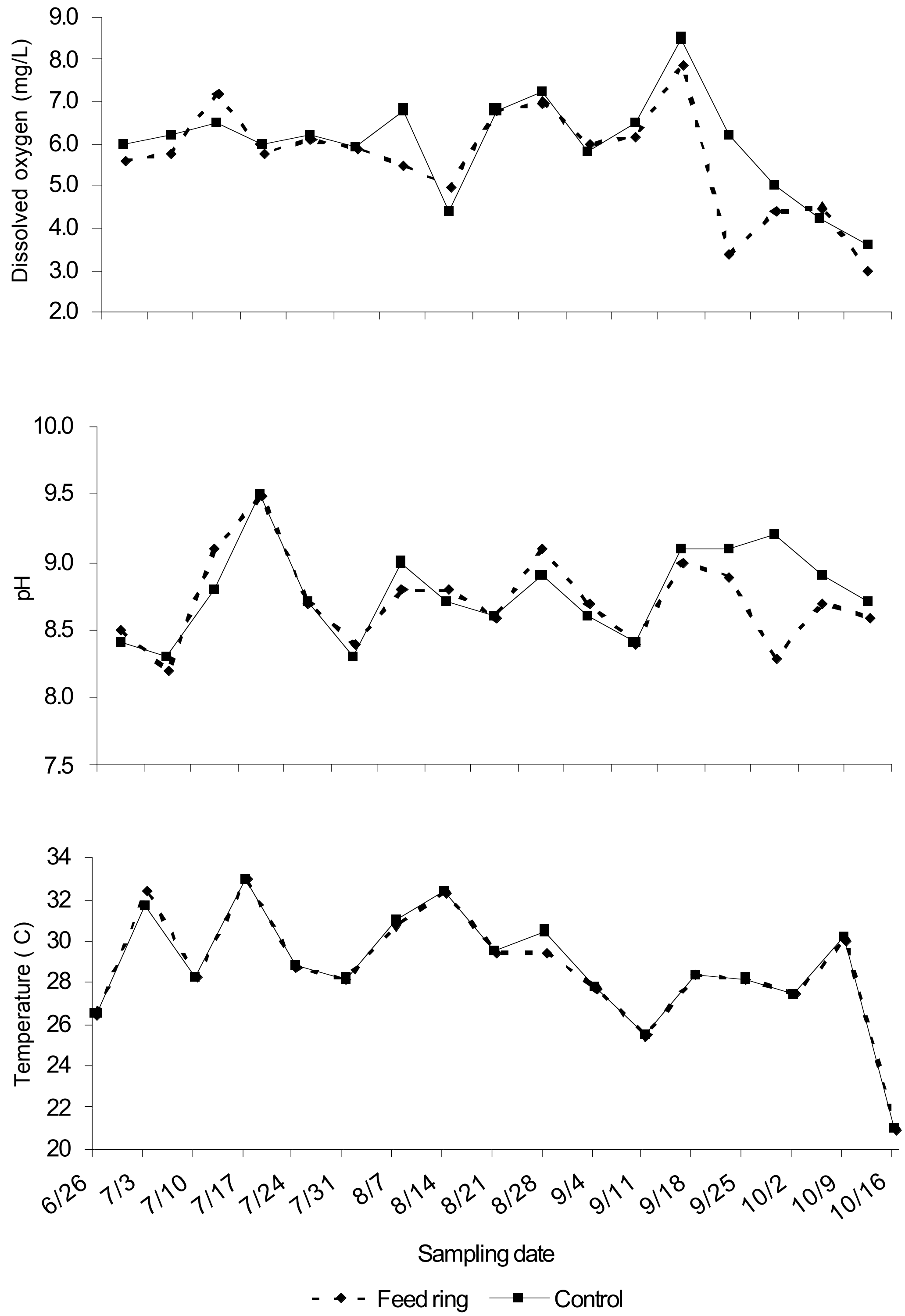

Figure 1. Mean afternoon water temperature, pH, and morning dissolved oxygen concentrations in plastic-lined ponds used to rear advanced channel catfish fingerlings fed using either feed rings or no feed rings at the Possum Kingdom State Fish Hatchery, Texas for 103 d from June to October 2007. No significant difference in mean values on any sampling date (*P* > 0.05).

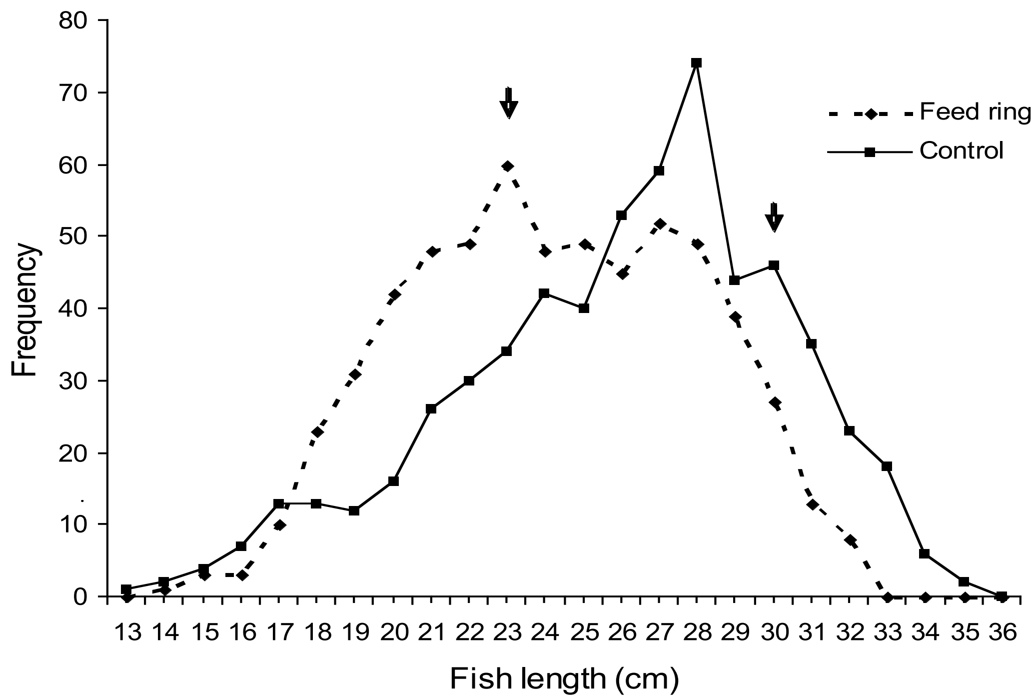

Figure 2. Distributions of total lengths of advanced channel catfish reared in plastic-lined ponds and fed using either feed rings or no feed rings at the Possum Kingdom State Fish Hatchery, Texas for 103 d from June to October 2007. Arrows indicate the 22.9- and 30.5-cm target lengths.

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