Growth, survival and fillet composition of paddlefish, *Polyodon spathula* (Walbaum) fed commercial trout or catfish feeds

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Abstract

Paddlefish are gaining increasing acceptance as an aquaculture species worldwide. Commercial trout feeds, containing high protein and lipid levels, are currently used in intensive culture; however, nutritional requirements of paddlefish are not currently known. A study was conducted examining the effects on growth, survival and fillet composition of juvenile paddlefish when fed commercial feeds differing in protein and lipid levels. Paddlefish larvae were first stocked in 14.0 m^3 round tanks and fed trout starter feeds for 43 days until trained to accept a 1.6 mm pellet. Paddlefish juveniles of mean weight ($\pm$ SE) 20 $\pm$ 0.27 g were randomly stocked into six 0.02 ha ponds at 12 500 ha^{-1} and fed floating commercial trout or catfish (lower protein and lipid) feeds, twice daily (08:00 and 15:30 hours) for 92–97 days. At harvest, there were no significant differences in final weight, percent survival, specific growth rate, relative growth and feed conversion ratio between treatments, which averaged 223.6 g, 96.2%, 2.5% day^{-1}, 10.2 and 1.98 respectively. Surface feeding activity index was significantly higher in ponds supplied with catfish feed than in ponds supplied with trout feeds. Relative pellet buoyancy was not a factor in feeding activity. Fulton's condition factor averaged 0.238, was not significantly different, and was similar to a reported value for extensively cultured paddlefish (zooplanktivore). There was no significant difference in liver somatic index between treatments, which averaged 1.91%. Percent protein and moisture of fillets averaged 14.9% and 80.9%, respectively, and were not significantly different between treatments. However, lipid content of fillets was significantly higher in paddlefish fed the trout feed (4.45%), compared with paddlefish fed the catfish feed (2.42%). Fillet lipid content for both treatments was higher than reported values for extensively cultured paddlefish. Percent abdominal fat was significantly higher (0.82%) in paddlefish fed the trout feed compared with paddlefish fed the catfish feed (0.52%). Results from this study indicate that paddlefish can be fed a commercial catfish feed labeled to contain 32% protein and 4.5% lipid without adverse effects on growth, survival and fillet composition, lowering production costs.

Keywords: paddlefish, feed trained, commercial feeds, protein level, lipid level

Introduction

The paddlefish, *Polyodon spathula* (Walbaum), is attracting increasing attention as an aquaculture species. Demand for paddlefish roe, which is processed into caviar, is expected to increase as restrictions are implemented on caviar trade from traditional sources. Currently, this demand is being met from wild harvest in only six states of the USA, out of 22 states where paddlefish are endemic (Graham 1997). Mims (2001) reported wholesale prices for paddlefish roe at US\$65–143 kg^{-1} and retail prices over US\$ 400 kg^{-1}. The meat produced from the roe fishery is currently finding markets in large urban centers where the similarity to sturgeon is recognized. However, Wang, Mims and Xiong (1995) reported high consumer acceptance of paddlefish meat, indicating the potential for a broader-based market if product is available. It is likely that increased demand for paddlefish will result in further restrictions on capture fisheries. Paddlefish are known to be highly vulnerable to fishing mortality

(Boreman 1997). In addition, they are late maturing with low turnover rates and cannot sustain high harvest levels. These factors indicate potential for further development of paddlefish aquaculture. Reservoir ranching has been proposed as an extensive method for paddlefish caviar production (Semmens & Shelton 1986; Onders, Mims, Wang & Pearson 2001), while polyculture with channel catfish, *Ictalurus punctatus* (Rafinesque), is indicated as a practical means of producing meat (Mims 2001; Schardein, Dasgupta & Mims 2002). In addition, 10 states have stocked or are stocking paddlefish for sport fishing or mitigation programmes (Graham 1997).

Availability of juveniles for stocking is limiting to expansion of paddlefish aquaculture. Propagation techniques are well developed (Mims 2001; Mims & Shelton 2005), but nursery strategies that will consistently produce practical growth and survival have been less defined. Early workers assumed that paddlefish required abundant populations of zooplankton in ponds, as they are naturally zooplanktivorous throughout life (Rosen & Hales 1981). However, survival was reported to be low and often variable (Purkett 1963) because of difficulty with sustaining adequate zooplankton densities in ponds via fertilization (Michaletz, Rabeni, Taylor & Russell 1982; Mims, Clark, Williams & Bayne 1995). Kroll, Van Eenannam, Doroshov, Hamilton and Russell (1992) observed that paddlefish greater than 12 cm total length (TL) are not obligate filter feeders, but will accept floating pellets in nursery ponds. Kurten, Hutson and Whiteside (1992) reported that a prepared diet was an adequate substitute for zooplankton in the initial culture stage, producing paddlefish averaging 35 mm TL in 15 days. Mims and Shelton (2005) summarized feeding of paddlefish with prepared diets, either in conjunction with fertilization in ponds, or exclusively in raceway culture.

Use of high-protein trout or salmon feed is typical in reports of feeding prepared diets to paddlefish (Graham, Hamilton, Russell & Hicks 1986; Tidwell, Webster & Mims 1991; Mims & Shelton 2005). The assumption that paddlefish need a high-protein feed is reasonable considering that their normal food, zooplankton, are protein rich (Webster, Mims, Tidwell & Yancey 1991; Mischke, Menghe & Zimba 2003). However, the nutritional requirements of paddlefish are not known. This is largely because of the difficulties encountered with providing the controlled environment called for in nutrition experiments (Lovell 1998), where paddlefish can remain viable for extended study periods. No data exists to support the necessity of feeding a high-protein diet in the nursery stage of paddlefish culture.

Here we present procedures used to produce paddlefish juveniles using prepared diets exclusively, in two phases. In phase I, larval fish were reared in tanks until trained to accept a floating pellet (1.6 mm). In phase II, the pellet-trained paddlefish were stocked at equal densities in ponds and presented with commercial trout or catfish feeds. The study objective was to evaluate growth, survival and fillet composition of the phase II paddlefish fed commercial feeds differing in protein (45% and 32%) and lipid (16% and 4.5%) levels.

Materials and methods

Phase I

The experiment was conducted at the Aquaculture Research Center, Kentucky State University, Frankfort, KY, USA. Broodstock paddlefish of Ohio River origin were propagated as described by Mims and Shelton (2005) in the spring of 2004. Resulting progenies were stocked at approximately five paddlefish L^{-1} at 5 days posthatch into two 14.0 m^3 (345 cm diameter × 150 cm deep) tanks supplied with flow-through de-chlorinated municipal water at 30 L min^{-1} and 18 °C. The tanks were flat bottomed, equipped with internal standpipes and aerated using a regenerative blower with ceramic diffusers. The water temperature was increased to 22–24 °C according to Melchenkov, Vinogradov, Erohina, Chertihin, Ilyasova, Bredenko, Sitnova, Chrisanfov, Kanidyeva, Bubunetz and Harzin (1996) and the paddlefish were fed a commercial feed (Rangen #0 Trout Starter, Rangen, Buhl, ID, USA) (55% protein, 17% lipid), using belt feeders.

The tanks were vacuum cleaned twice daily and dissolved oxygen was monitored to insure at least 75% saturation. Paddlefish were examined twice weekly under a binocular dissecting microscope to monitor development, condition and growth relative to feed particle size. When appropriate, feed size was increased gradually, first to Rangen #1 Trout Starter (55% protein, 17% lipid), then to Melick 1.0 mm SS (slow sink) (Melick Aquafeed, Catawissa, PA, USA) (50% protein, 20% lipid), and finally to Rangen EXTR 450, 1.6 mm (floating pellet) (45% protein, 16% lipid). Paddlefish cannot consume feed from the bottom. Therefore, the feeding regime objective was to provide feed particles on the surface or in the water column continuously. When the paddlefish reached average length 2 cm, they were split into two additional tanks of the same size and configuration. Feeding was continued through day 43.

Phase II

Experimental ponds and stocking

The study was conducted in six 0.02 ha rectangular ponds. The ponds were filled just prior to stocking and were not fertilized. Koi carp, *Cyprinus carpio* L. (average weight 4.7 kg) were stocked at 395 ha^{-1} (Boyd & Tucker 1998) for control of filamentous algae and rooted macrophytes. The koi were fed a maintenance ration of a sinking pellet daily, an equal amount in each pond and in a consistent feeding area. Koi were fed just before the paddlefish each morning. The ponds were stocked either with all male or all female koi to prevent reproduction. Each pond was covered with netting to exclude avian predators and a 1.5-HP electric splash type surface aerator with a dusk-to-dawn photocell timer was positioned in the center of each pond.

Phase I paddlefish were stocked into the experimental ponds on 4 June 2004 at a rate of 250 paddlefish per pond (12 500 paddlefish ha^{-1}). Mean stocking weight ($\pm$ SE) was 20 $\pm$ 0.27 g. Three replicate ponds were randomly assigned to each of the two treatments. Paddlefish were fed a maintenance ration of the 1.6 mm floating pellet (Rangen EXT 450) on the day of stocking and through the morning of the fifth day after stocking to acclimatize them to surface feeding in the ponds.

Commercial feeds and feeding regimen

Measured feeding was begun during the afternoon (15:30 hours) feeding on 9 June 2004. One treatment was fed the Rangen EXT 450 1.6 mm floating pellet (45% protein, 16% lipid), while the other was fed Aquafare Koi-E (US Energy Partners, LLC, Russell, KS, USA) 1.6 mm (floating pellet) (32% protein, 4.5% lipid). This feed was selected because it was available in the desired size as well as the desired protein and lipid levels. After the first day, feedings were broadcast over the pond surface at 08:00 and 15:30 hours. The morning feeding consisted of 25% of the total daily ration and the afternoon feeding was comprised of the remaining 75%. Aerators were off until 1 h after the morning feeding, then on until the afternoon feeding. Following the afternoon feeding, aerators remained off until automatically switched on at dusk by the photocell timers (about 6 h later).

Initially, paddlefish were fed at 9% of body weight. Thereafter, they were sampled every 2 weeks and feeding rate was adjusted (Table 1). Larger pellets (3.2 mm) were gradually introduced to the feeding regimen beginning 7 July 2004 until a ratio of 25% small pellets to 75% large pellets was attained over a 3-week period. The large pellets fed to paddlefish in the trout feed treatment were from the same manufacturer and of the same composition as the smaller pellets fed to this treatment. The large pellets fed to paddlefish in the catfish feed treatment were from Rangen (Production 32) and of the same protein and lipid levels as the small pellets from Aquafare.

The feeds were analysed by a commercial analytical laboratory (Eurofins Scientific, Woodson-Tenent Laboratories Division, Des Moines, IA, USA) to confirm labelled protein and lipid levels (Table 2). Moisture, fibre and ash were also determined. Nitrogen-free extract (NFE) was calculated by difference (Barrows & Hardy 2001) and available energy was calculated according to the procedure described by King (2004). The catfish feed was furnished to the laboratory as a 75% large pellet (Rangen Production 32) and 25% small pellet (Aquafare Koi-E) mixture. Laboratory procedures were according to AOAC (1990).

In order to test relative buoyancy of the feeds, 50 feed pellets were counted into glass culture dishes (19 cm diameter $\times$ 6.5 cm deep), three dishes for each treatment. One litre of tap water was poured into each dish and stirred for 1 min to wet the pellets, and then the dishes were left undisturbed. The tendency for the pellets to sink or remain floating was observed over time.

Feeding activity index (FAI)

A relative ranking of feeding activity was recorded for the treatment ponds daily from 1 July to 6 September

Table 1 Average biomass of juvenile paddlefish (assuming 100% survival) in each pond at the beginning of each feeding period (14 days) and percent of body weight fed daily during the period

	Feeding period						
	1	2	3	4	5	6	7
Average paddlefish biomass (kg)	5.0	7.6	15.6	20.1	30.7	37.9	47.4
Percent body weight fed	9.0	7.5	4.4	4.5	3.0	4.2	3.8

Table 2 Proximate composition (percent wet weight) of two commercial feeds fed to juvenile paddlefish in ponds and calculated available energy from protein, lipid and NFE

	Diet type	
Diet component	Trout	Catfish
Moisture	8.3	7.7
Protein	43.6	33.8
Lipid	17.3	7.5
Fibre	1.2	4.7
Ash	9.1	6.9
NFE	20.5	39.5
Available energy* (kcal kg^{-1})		
protein	1831	1419
Lipid	1427	619
NFE	461	889
Total	3719	2927

*Available energy values calculated (King 2004) from the average of protein, lipid and NFE digestibility of trout/salmonids and channel catfish (Piper, McElwain, Orme, McCraren, Fowler & Leonard 1982).
NFE, nitrogen-free extract.

2004. The ranking was recorded 0.25 h after the afternoon feeding. A rank scale of 1 to 10 was used with a rank of 1 assigned to low surface feeding activity and 10 assigned to vigorous surface feeding. Weather conditions were also recorded at the time of feeding as sunny, partly cloudy, mostly cloudy, cloudy (sun obscured), rain or wind.

Water quality monitoring and management

Dissolved oxygen, pH and water temperature were measured daily at 08:00 and 15:30 hours Dissolved oxygen and temperature were measured using an YSI Model 57 meter (Yellow Springs Instruments, Yellow Springs, OH, USA); pH was measured with an Oakton Model 510 meter (Oakton Instruments, Vernon Hills, ILL, USA). Total ammonia nitrogen (TAN) and nitrite nitrogen were measured twice weekly; TAN by the nesslerization method and nitrite by the diazotization method. Both methods were per APHA (1998) as adapted for use with the HACH DR/2500 Spectrophotometer (HACH Co., Loveland, CO, USA). Alkalinity was measured bi-weekly by titration with a HACH Digital Titrator. Chlorophyll concentrations differentiated by algae class were measured weekly using a bbe Cuvette Flourometer (bbe Moldaenke GmbH, Kiel-Kronshagen, Germany). When total chlorophyll *a* concentrations from green algae *Chlorophyta* spp. and blue-green algae *Cyanophyta* spp. exceeded 150 $\mu g L^{-1}$, or when afternoon pH exceeded 9.0, ponds were flushed with fresh water to moderate algal populations. Sodium chloride was added to the ponds to maintain a prophylactic level above 3 $mg L^{-1}$ for protection from nitrite toxicity (Tucker, Francis-Floyd & Beleau 1989). Chloride was measured by the mercuric nitrate method (APHA 1998). Aeration was provided continuously from 09:00 to 15:30 hours to prevent super-saturation of dissolved oxygen, as well as from dusk to dawn.

Harvest

Paddlefish were seine-harvested between 8 September and 14 September 2004. Total weight and number of paddlefish were recorded for each pond and 75 fish from each pond were individually weighed and measured for TL. Fifteen paddlefish from each pond were randomly sampled, chill-killed in ice water and individually weighed. Livers and abdominal fat deposits were removed from each fish and weighed. Fillets were removed and bulk ground in a food blender to a paste consistency. The samples were placed in polyethylene bags and stored at −84 °C. The ground fillets were analysed to determine protein, lipid, moisture and ash by Woodson–Tenent Laboratories according to AOAC (1990).

Final weight at harvest was used to define paddlefish growth. Other growth parameters examined included specific growth rate (SGR) and relative growth (RG). Three physiological indices of growth were examined: Fulton's condition factor (FCF) (Anderson & Gutreuter 1982); liver-somatic index (LSI) (Busacker, Adelman & Goolish 1990); and percent abdominal fat. Feed conversion ratio (FCR) was also calculated for the trout and catfish feeds.

Statistical analysis

Data for harvest weights, FCF, LSI and abdominal fat were analysed by analysis of variance (ANOVA). Liver-somatic index and abdominal fat were arcsin transformed prior to analysis (Zar 1984). Percent survival, FCR, SGR and RG were compared by *t*-test, as were proximate fillet compositions. Replicate means were used as observations for *t*-test analysis. Proximate fillet compositions, survival and SGR were arcsin transformed. Feeding activity index was analysed by ANOVA. Diet, time and diet–time interaction were included in the model, as well as the effect of weather and diet–weather interaction. All ANOVA was per the general linear model procedure of the statistical analysis software system (SAS 2001). In all statistical analysis, when $P<0.05$, the difference was considered to be significant.

Results

Mean final weights were not significantly different between treatments ($P>0.05$) and averaged 223.6 g overall. Specific growth rate, RG, FCR, FCF and liver somatic index were also not significantly different between treatments, averaging 2.57% day^{-1}, 10.2%, 1.98%, 0.238% and 1.91% respectively (Table 3). Survival averaged 96.2%, and was not significantly different between treatments. Percent abdominal fat was significantly higher ($P<0.05$) in paddlefish fed the trout feed (0.82%) compared with paddlefish fed the catfish feed (0.52%) (Table 3).

Percent protein (14.9%) and moisture (80.9%) of the fillets were not significantly different between treatments (Table 4). The percent lipid content of the fillets was significantly different ($P<0.05$); percent lipid in paddlefish fed the trout feed was 4.45% and percent lipid in paddlefish fed the catfish feed was 2.42% (Table 4).

In the buoyancy trial, all pellets in both treatments remained floating after 40 h. Feeding activity index was significantly higher in ponds fed the catfish diet than in ponds fed the trout diet. Mean FAI (± SE) was 7.10 ± 0.14 in the catfish diet ponds and 3.61 ± 0.14 in the trout diet ponds. Time–treatment interaction was not significant. There was no interaction between weather conditions and treatments; overall, FAI was highest on rainy days (5.80) and lowest (4.56) on windy days (Table 5).

Morning and afternoon dissolved oxygen was not significantly different between treatments averaging 6.8 and 9.9 mg L^{-1} respectively. Morning dissolved oxygen ranged from 3.4 to 9.4 mg L^{-1} and afternoon dissolved oxygen ranged from 5.4 to 20 mg L^{-1}. Morning and afternoon pH was also not significantly different averaging 7.9 and 8.7 respectively. Pond water temperatures were similar with morning and afternoon temperature averaging 23.8 and 25.7 °C respectively. Morning and afternoon water temperature range was 18.4–29.8 °C and 20.6–29.7 °C respectively. Total alkalinity was not significantly different and averaged 95.7 mg L^{-1}. Average nitrite concentrations remained below 0.08 mg L^{-1} in ponds fed the trout feed except during week 8, when nitrite concentration averaged 0.11 mg L^{-1}. In ponds fed

Table 3 Final weight, SGR, RG, FCR, FCF, LSI, percent survival and percent abdominal fat of juvenile paddlefish fed commercial trout or catfish feeds*

	Feed type	
	Trout	Catfish
Final weight (g)	227.2 ± 14.6[a]	220 ± 11.5[a]
SGR (% day^{-1})†	2.59 ± 0.03[a]	2.54 ± 0.10[a]
RG‡	10.4 ± 0.7[a]	10.0 ± 0.6[a]
FCR§	1.93 ± 0.11[a]	2.02 ± 0.12[a]
FCF¶	0.240 ± 0.002[a]	0.236 ± 0.002[a]
LSI ‖	1.98 ± 0.1[a]	1.84 ± 0.1[a]
Survival (%)	96.1 ± 1.1[a]	96.3 ± 1.9[a]
Abdominal fat (%)	0.82 ± 0.1[a]	0.52 ± 0.1[b]

*Listed values are means (± SE) for three replications. Means in a row with differing superscript are significantly different ($P<0.05$).

†Specific growth rate (SGR) (% day^{-1}) = ((ln W_t–ln W_i)/T)100, where W_t and W_i are mean final weight and mean initial weight respectively (g) and T is the culture period (days).

‡Relative growth (RG) = $W_t - W_i/W_i$.

§Feed conversion ratio (FCR) = total diet fed (kg)/total wet weight gain (kg).

¶Fulton's condition factor (FCF) = (W_{ind}/TL^3) × 10^5, where W_{ind} is the individual final weight (g) and TL the total length (mm).

‖Liver somatic index (LSI) = (liver weight (g) /W_{ind})100.

Table 4 Proximate composition (percent wet weight) of fillets of juvenile paddlefish fed commercial trout or catfish feeds in ponds*

	Feed type	
	Trout	Catfish
Moisture	79.56 ± 0.13[a]	82.21 ± 0.96[a]
Protein	15.31 ± 0.44[a]	14.48 ± 0.92[a]
Lipid	4.45 ± 0.22[a]	2.42 ± 0.38[b]

*Values are means (± SE) for three replications. Means in a row with differing superscript are significantly different ($P<0.05$).

Table 5 Feeding activity index (FAI) of juvenile paddlefish fed two commercial trout or catfish feeds in ponds during different weather conditions*

Weather condition	FAI
Sunny	5.43 ± 0.15[a]
Partly cloudy	5.29 ± 0.25[a]
Mostly cloudy	5.33 ± 0.20[a]
Cloudy (sun obscured)	5.48 ± 0.20[a]
Rain	5.8 ± 0.29[a]
Wind	4.56 ± 0.26[b]

*Values are means (± SE) for six replications. Means with differing superscript are significantly different ($P<0.05$).

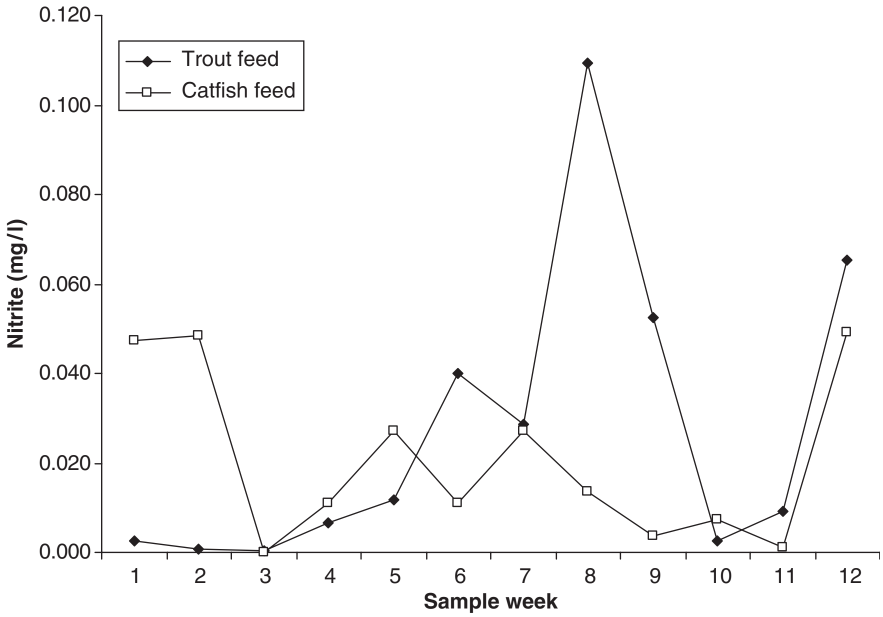

Figure 1 Changes in nitrite concentration over the study period.

the catfish feed, average nitrite concentration remained below 0.06 mg L^{-1} throughout the study (Fig. 1). Average TAN remained below 0.40 mg L^{-1} in the trout diet ponds, except during week 8 when TAN averaged 0.78 mg L^{-1}. Average TAN remained below 0.40 mg L^{-1} in ponds fed the catfish diet throughout the study (Fig. 2).

Discussion

In this study, growth of paddlefish fed a commercial catfish feed was similar to paddlefish fed a commercial trout feed. Both diets produced paddlefish of suitable size for stocking in either reservoir ranching or polyculture systems at the end of the study. Production costs can be reduced substantially by reducing the protein content of diets fed to fish, especially when animal proteins are reduced. Currently, delivered feed costs to fish farmers in Kentucky are $US275–330 metric tonnes $^{-1}$ for catfish diet (ARKAT 2004) and US$770–880 metric ton $^{-1}$ for trout diet (Rangen 2004).

Both treatments responded to increases in feeding rate and growth was maintained at a rapid rate throughout the study as indicated by RG. Daily gains were also similar for each treatment as indicated by SGR. Final weights and lengths were similar to those reported by others. Graham *et al.* (1986) reported achieving advanced fingerling-size paddlefish in fertilized ponds during a 140 day growing season. In this study, the overall growing season for phase I and II was also 140 days. Mims and Shelton (2005) reported expected growth to 150 g and 35 cm TL in 180 days for paddlefish stocked as first-feeding larvae in fertilized ponds at 62 000 ha $^{-1}$.

Although little uneaten feed was observed in the ponds prior to the morning feeding, satiation feeding of paddlefish is difficult to determine and can only be assumed for this study. It is likely that the koi consumed some feed, although interference with paddlefish feeding by the koi was not observed. It may be possible to increase feeding rates above those reported in this study within the limits of water quality. Water quality parameters remained well within the limits recommended for paddlefish during this study (Mims 2001), except during week 8, when unionized ammonia levels may have exceeded the recommended 2 mg L^{-1} limit in the trout feed treatment (no adverse effects were observed). In larger production ponds, shorter grow-out periods might be achieved by increasing feeding rate, as paddlefish are known to grow rapidly (Ruelle & Hudson 1977; Pasch, Hackney & Holbrook II 1980). Increased stocking density is another possibility and both of these scenarios should be studied further.

Survival was not affected by any treatment in this study. Protection from predators, afforded by netting

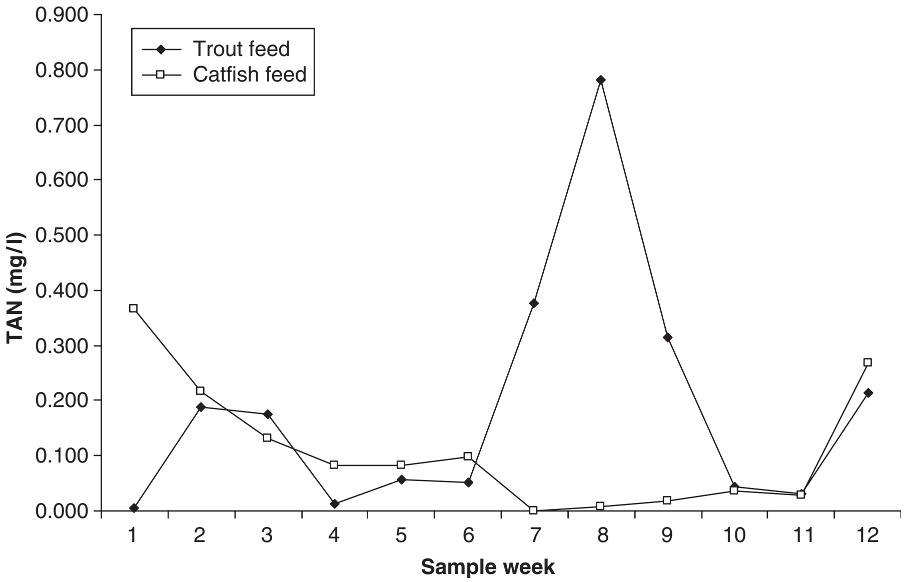

Figure 2 Changes in total ammonia nitrogen (TAN) concentration over the study period.

over the ponds, likely contributed greatly to the high survival experienced in this study. Paddlefish are highly vulnerable to predation. Covering production ponds with netting may not be practical; however, this should be considered because of the potential high value of stocking size paddlefish. Feeding a floating pellet may also have contributed to survival. Tidwell *et al.* (1991) stocked paddlefish at age 47 days (3.6 g, 120 mm TL) at 4940 or 9880 ha^{-1} and fed a sinking trout feed for 131 days. Survivals were 72.5% and 41.8% respectively. Floating feeds are more suitable for paddlefish as their initial response to feed presentation is slow and they will not feed on the pond bottom.

Feed conversion ratios from this study were similar to those reported for channel catfish, but higher than expected values for trout or salmon. Mims and Shelton (2005) reported expected values ranging from 2:1 to 4:1 for paddlefish fed a floating trout feed (1.6 mm). Values in this study were at the lower end of this range; however, FCR results from this study may be more a function of feed presented than feed consumed, especially with regard to the trout feed treatment. Surface feeding activity was significantly higher in ponds fed the catfish feed than in those fed the trout feed, regardless of weather or the passage of time over the study period. Pellet buoyancy was not a factor, that is, paddlefish fed the trout feed were not waiting for the pellets to sink through the water column. Burke and Bayne (1986) reported that paddlefish stocked at 990 ha^{-1} depressed zooplankton densities with a concurrent increase in phytoplankton standing crop. In this study, the stocking density was 12 500 ha^{-1}, and phytoplankton blooms were frequent. Therefore, it is unlikely that zooplankton densities were sufficient to support growth or significantly contribute to nutrition in either treatment.

Differences in digestible energy of the feeds are a more likely explanation of the differences in feeding activity. Fish are thought to feed in order to satisfy their energy requirements and to adjust feed consumption in proportion to energy level. According to Barrows and Hardy (2001), at the extremes of dietary energy content, fish consuming feed of a lower energy level gain weight at a rate comparable with those consuming a higher energy feed, but they consume more feed in order to do so. In previous work at Kentucky State University, paddlefish stocked at 25 000 ha^{-1} were observed feeding vigorously at the surface on trout feed. It is reasonable to conclude from this study that based on the FAI, the trout and catfish feeds represented extremes of digestible energy and FCR for the trout feed was actually lower than the calculated value. Whether this possibility would significantly affect the economy of feeding trout feed to paddlefish is another area needing further study.

Despite the above, it does not necessarily follow that the catfish feed was nutritionally insufficient. Mims and Knaub (1993) reported the FCF of paddlefish reared extensively, ranging in age from 11 to 56 weeks and from 318 to 890 mm TL, at 0.242, which is similar to values obtained in this study for both treatments. Decker, Crum, Mims and Tidwell (1991) reported proximate muscle compositions of paddlefish ranging in size from 394 to 667 g that were also reared extensively and described as not being in a nutritionally depleted state. Muscle protein composition of these paddlefish averaged 15.8%, which is similar to this study. The average moisture reported (81.9%) is also similar to this study. In the present study, lipid content of the fillets was significantly higher in paddlefish fed the trout feed. However, the lipid content of fillets from paddlefish fed the catfish feed (2.42%) was higher than the value reported for the extensively cultured fish (1.53%). Additionally, abdominal fat was significantly higher in paddlefish fed the trout feed than in those fed the catfish feed. Comparisons with wild or extensively cultured paddlefish are not available; however, it does not appear that the paddlefish fed the catfish feed in this study were deficient in stored energy reserves. This would be an important factor when paddlefish juveniles are over-wintered for spring stocking, as feeding activity of paddlefish ceases during winter.

Indications from this study are that commercial catfish feeds containing 32% protein and 4.5% lipid will furnish essential nutrients, support rapid growth and supply sufficient energy for the pond production of stocker size paddlefish. In addition to those mentioned above, future studies should include determining the digestibility of nutrients by paddlefish and investigating the bioenergetics of this species so that custom feeds can be formulated.

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