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Growth and Yield of Paddlefish, *Polyodon spathula*, Reared at Two Densities in Earthen Ponds in Kentucky

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ABSTRACT

Paddlefish, *Polyodon spathula*, fingerlings with a mean weight of 3.6 g were stocked at 4,940 and 9,880 fish/ha in 0.04-ha earthen ponds and cultured for 131 days. Fish were fed a prepared diet (50% crude protein) at 15% of total body weight daily until a maximum rate of 114 kg/ha/day was attained, the feeding rate was not increased thereafter. Mean harvest weights for fish stocked at 4,940 and 9,880 fish/ha were 107 and 139 g, respectively ($P > 0.05$). Percentage survival, food conversion ratio, and specific growth rate of paddlefish was not significantly different ($P > 0.05$). Data indicate that paddlefish can be stocked at a higher density than previously reported if supplemental feed is provided.

INTRODUCTION

Considerable interest in producing paddlefish, *Polyodon spathula*, for stock enhancement, remediation, and for foodfish and caviar exists in the United States. Although culture of paddlefish was first attempted in the early 1900s (1), it was not until the early 1960s that paddlefish eggs were successfully collected, fertilized, and hatched (2). Techniques to spawn and rear paddlefish have continued to develop (3–6).

Paddlefish longer than 120 mm are filter feeders that consume zooplankton (7). Natural production of paddlefish in reservoirs has produced between 11 to 22 kg of paddlefish/ha (8, 9). These values are in agreement with extensive rearing of the zooplanktivorous bighead carp, *Aristichthys nobilis*, with production yields of approximately 22 kg/ha (10). When reared in polyculture with channel catfish, *Ictalurus punctatus*, where the channel catfish are fed a prepared diet, yields up to 460 kg/ha of paddlefish have been achieved (11). This low production potential limits commerical-scale rearing of paddlefish in ponds. In pond culture, stocking density depends on the size of the pond, fertilization of the pond, availability of natural food, supplemental feeding, and water quality (especially levels of dissolved oxygen and waste products) (12).

Fingerling paddlefish have been reported to consume a prepared diet (5, 13). Feeding a prepared diet to paddlefish reared in ponds may enable stocking densities to be increased and also result in increased yields similar to those found in commerical channel catfish culture. The objective of this study was to investigate the effect of feeding a prepared diet on growth and yield of paddlefish stocked at 2 different densities reared in earthen ponds in Kentucky.

MATERIALS AND METHODS

Fingerling paddlefish (mean individual weight 3.6 ± 0.5 g; mean total length 12.0 ± 1.0 cm; 47 d old) were randomly stocked into 0.04-ha ponds of the Aquaculture Research Center, Kentucky State University on 20 May, 1988. Prior to stocking, paddlefish were held in organically-fertilized 0.02-ha ponds. Two ponds were randomly stocked with either 9,880 fish/ha or 4,940 fish/ha. These stocking rates correspond to a commerical channel catfish density and one-half a commercial density, respectively. There were 2 replications per treatment. Ponds were filled immediately prior to stocking and were not previously fertilized. Zooplankton samples were not taken, since the effect of stocking density and feeding a prepared diet on growth was the main objective. Fish were fed immediately after stocking and trained to actively consume the prepared diet within 10 d after stocking.

All fish were fed a commercially prepared diet (Zeigler Trout Starter #5102, 50% crude protein and 10% crude fat) at 15% of body weight daily throughout the study, with a max-

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TABLE 1. Summary of water analyses for ponds containing two densities of paddlefish.[1]

Variable	Stocking density (number/ha) 4,940	9,880
Temperature (°C)		
Morning	22.8 ± 0.7	22.4 ± 0.0
Afternoon	26.1 ± 0.1	25.3 ± 1.1
Dissolved oxygen (mg/l)		
Morning	7.5 ± 0.1*	7.1 ± 0.0*
Afternoon	10.7 ± 1.3	10.8 ± 0.4
pH	8.29 ± 0.66	8.29 ± 0.44
Total ammonia (as mg/l N)	1.52 ± 1.10	0.38 ± 0.30
Nitrite (as mg/l N)	0.220 ± 0.113	0.098 ± 0.076

[1] Values are means ± SE for two replications. Means within a row having an "*" were significantly different ($P < 0.05$).

imum rate of 114 kg/ha/day (12). Since paddlefish are filter-feeders, a diet with small particle size is desired, even as fish grow. Calculated feed allowance was divided into 3 equal amounts and fed 3 times daily (0900, 1300, and 1600 hr) in a specified corner of the pond. Feed allowance was adjusted at the beginning of each month based on weights of 40 sampled fish from each pond and every 2 weeks by assuming a 1.5 food conversion (14). Fish were individually weighed (g) and total length measured (cm). At monthly samplings, stomach contents of 10 fish from each pond were suctioned and qualitatively analyzed for the presence or absence of prepared diet using a dissecting microscope. After 131 days, the fish were harvested, counted, weighed, and measured.

Dissolved oxygen and temperature were monitored twice daily (0900 and 1800 hr) at 0.75 m depth using a YSI Model 57 oxygen meter. When the dissolved oxygen level of any pond was predicted (by graph) to decrease to below 3.0 mg/liter, emergency aeration was provided. Ammonia, nitrite, and alkalinity were measured weekly using a DREL/5 spectrophotometer (Hach Co., Loveland, Colo.), and pH was measured weekly in the afternoon using an electronic pH meter (Omega Engineering, Stanford, Conn.).

Fish were not fed 24 hr prior to harvest. Total number and weight of fish in each pond were determined. Forty fish were randomly sampled from each pond and each fish was

TABLE 2. Individual fish lengths and weights, percentage survival, food conversion ratios (FCR), specific growth rates (SGR), and protein efficiency ratios (PEF) for paddlefish raised at two densities in earthen ponds in Kentucky.[1]

Parameter	Stocking density (number/ha) 4,940	9,880
Indiv. length (cm)	34.4 ± 2.6	37.0 ± 3.3
Indiv. weight (g)	107.1 ± 34.7	139.4 ± 42.3
Survival (%)	72.5 ± 14.5	41.8 ± 12.5
FCR	9.8 ± 4.1	13.0 ± 6.3
SGR	2.7 ± 0.3	2.7 ± 0.2
PER	0.43 ± 0.07	0.49 ± 0.05

[1] Values are means ± SE of two replications. Means with an "*" were significantly different ($P < 0.05$).

weighed to the nearest gram and total length measured to the nearest cm. Food conversion ratio (FCR), specific growth rate (SGR), and protein efficiency ratio (PER) were calculated as follows: FCR = total feed fed (kg)/total wet weight gain (kg); PER = wet weight gain (kg)/amount of protein fed (kg); SGR (%/day) = ($\log W_t - \log W_i/T$) × 100, where W_t is the weight of fish at time t, W_i is the weight of fish at time 0, and T is the culture period in days.

Data were analyzed by Student's *t* test using the SAS TTest procedure (15). Percentage survival and specific growth rates were transformed to arc sin values prior to analysis (16).

RESULTS AND DISCUSSION

There were no significant differences ($P > 0.05$) in mean temperatures, pH, dissolved oxygen, total ammonia, and nitrite in ponds between the 2 stocking densities (Table 1). Mean morning dissolved oxygen values were significantly ($P < 0.05$) different (7.5 and 7.1 for ponds stocked at 4,940 fish/ha and 9,880 fish/ha, respectively). All water quality parameters were considered within acceptable limits for warmwater fish culture (17).

There were no significant differences ($P > 0.05$) in individual fish lengths, individual fish weights, survival, food conversion ratios (FCR), specific growth rates (SGR), and protein efficiency ratio (PER) between fish stocked at two different densities (Table 2). Individual fish weights were 107.1 and 139.5 g for fish stocked at 4,940 fish/ha and 9,880 fish/ha, respectively (Fig. 1). Individual fish weights in this study were higher than reported by Graham et al. (56 g) (13). Methods to increase density and production of large (100 g) fingerlings are desirable due to the need for large fingerlings to stock in reservoirs (12) and for polyculture (11). Tidwell and Mims (18) reported high mortality of small paddlefish (10 g) fingerlings when stocked with large (400 g) channel catfish.

Percentage survival averaged 57% overall after 131 days, which is in agreement with values reported by Semmens (19). Graham et al. (13) reported percentage survival at the end of a growing season averaged 38%. Stocking density had no significant ($P > 0.05$) effect on food conversion ratios (FCR) which were 9.8 and 13.0 for fish stocked at 4,940 fish/ha and 9,880 fish/ha, respectively. Previous studies have not presented FCR values. Gut analysis revealed that the prepared diet was being consumed by the fish. This is in agreement with Brandt (5), who reported that paddlefish would consume a prepared diet. Specific growth rate (SGR) was not significantly different ($P > 0.05$) and was 2.5%/day and 2.8%/day for paddlefish stocked at 4,940 fish/ha and 9,880 fish/ha, respectively. Protein efficiency ratio (PER) was not significantly ($P > 0.05$) different between fish stocked at 4,940 fish/ha (0.25) and fish stocked at 9,880 fish/ha (0.20).

The high FCR indicates that paddlefish may not consume a dry diet as efficiently as other fish species. A small particle size in a diet is desirable for feeding filter-feeders and should not have adversely affected growth. Michaletz (7) reported that paddlefish consume *Daphnia* sp., which are present in high numbers in ponds during the spring in Kentucky, throughout the life-cycle. Fish were trained to feed in a specific area of the pond and the rate of diet application should have allowed fish to consume the diet. In this study, paddlefish fry were consuming the prepared diet within 10 days after stocking. Graham et al. (13) reported that paddlefish fry consumed a prepared diet within 13–18 days. Young paddlefish will consume a prepared diet when fed in close proximity to the fish. However, paddlefish do not actively search for the diet (13). Diet that was not consumed while in the water column settled to the pond bottom and was not eaten. Uneaten feed could act as a fertilizer and maintain zooplankton populations (20). Diets that remain in suspension for longer periods of time may allow paddlefish to consume prepared diets more efficiently and reduce FCR values. Reduced growth performance associated with white sturgeon, *Acipenser transmontanus*, larvae fed prepared diets has been attributed to imprinting of larvae to live foods after initiation of exogenous feeding (21). Paddlefish fry used in this study fed on live foods after the start of exogenous feeding, so imprinting onto live foods may have been possible. Paddlefish fry fed prepared diets from initiation of exogenous feeding had a high percentage (>80%) of fish consuming the diets (22).

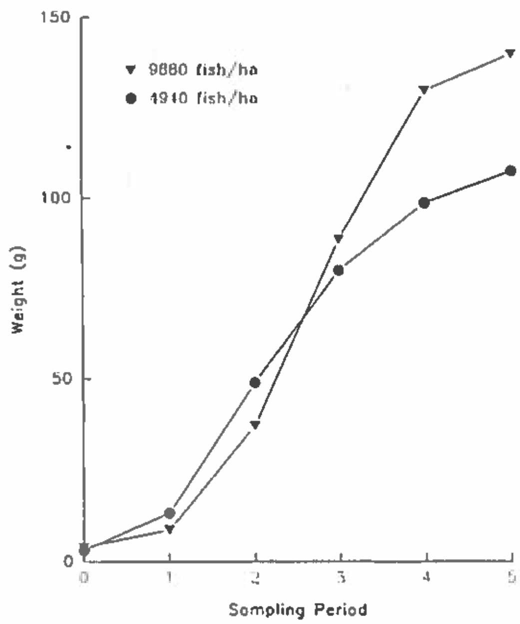

FIG. 1. Weight (g) of paddlefish fingerlings stocked at two densities (4,940 and 9,880 fish/ha). Values are means of two replications.

The lack of significant difference in growth, survival, and food conversion probably indicates that carrying capacity was not reached. Higher stocking rates may result in increased yields without a decrease in growth rate and percentage survival. However, the lower (although not statistically significant) survival in fish stocked at 9,880 fish/ha compared to fish stocked at 4,940 fish/ha may indicate that this stocking density is too high. However, stocking paddlefish at 9,880 fish/ha and feeding a prepared diet 3 times daily doubled the gross yield reported by Semmens and Shelton (11) in fertilized ponds. This increased stocking density may allow for more intensive culture of paddlefish than previously reported.

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