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The Effect of Water Temperature on Growth and Survival of Largemouth Bass during Feed Training

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Abstract.—Water temperature could be an important factor during the feed training phase of largemouth bass *Micropterus salmoides* production, as it could affect appetite and starvation time. We evaluated three water temperatures during largemouth bass feed training. Pond-reared largemouth bass fingerlings (weight = 2.1 ± 0.6 g [mean ± SE]) were randomly stocked into twelve 0.5-m^3 polyethylene cages to achieve a stocking density of 350 fish per cage. The cages were suspended in six 3,800-L polyethylene tanks with a common water source housed in a greenhouse with four replicate cages per water temperature treatment (20, 24, and 28°C). Each tank contained two cages, and there were two tanks per treatment temperature. In each cage, fingerlings were initially fed freeze-dried krill, then gradually weaned onto a commercial pellet (floating trout feed; 1.5 mm) over a 24-d period according to an established training protocol. At harvest, the average weight and the percentage of fish successfully trained to commercial feed were significantly different among temperatures ($P \leq 0.05$), increasing as water temperature increased (weights averaged 5.4, 6.8, and 7.8 g and percent trained averaged 70, 82, and 90% for fish feed-trained at 20, 24, and 28°C, respectively). The results from this experiment indicate that water temperature has a significant effect on feed training success and the average weight of feed trained largemouth bass.

Largemouth bass *Micropterus salmoides* are fairly unusual for a cultured species, as they have to be trained to accept prepared diets. Unlike channel catfish *Ictalurus punctatus* and rainbow trout *Oncorhynchus mykiss*, largemouth bass fry have not been successfully trained to accept prepared diets (Brant et al. 1987; Williamson et al. 1993). Therefore, bass fry are usually raised in fertilized nursery ponds or in tanks until they reach 4–6 cm total length (TL) (Tidwell et al. 2000). At this size, the juveniles are then crowded into tanks at high densities and presented highly palatable food items at frequent intervals (Kubitza and Lovshin 1997). Over the period of 10–14 d, the juveniles are gradually transitioned to commercial dry diets.

Feed-training success of largemouth bass is highly variable, ranging from 13% to 90% (Lovshin and Rushing 1989; Sloane 1993; Kubitza and Lovshin 1997; Skudlarek et al. 2007). As the cost of feed-trained largemouth bass fingerlings is relatively high (approximately US$0.20–0.25 per 7-cm-TL fish; Robert Mayer, Mayer's Fish Farm, Bardstown, Kentucky, personal communication), success rates during feed training can have a major effect on production costs. Training success can be influenced by many variables including initial fish size and condition, the acceptability of the training diet, environmental conditions in the training system, stocking densities, and the genetic potential of the particular strain (Williamson 1983). Several studies have described and tested different initial food items, such as ground fish, fish eggs, moist pellets, and freeze-dried krill (FDK) used for feed training largemouth bass fingerlings (Snow 1965; Anderson 1974; Kubitza and Lovshin 1997; Skudlarek et al. 2007). However, little to no research has been conducted on the optimal physical conditions during the feed-training period.

Temperature is the single most pervasive environmental factor for poikilothermic animals such as fish (Stickney 1979). Temperature significantly affects the growth and body composition of fish by controlling feed consumption and food retention time (Coutant 1975). In a study performed by Tidwell et al. (2003), higher culture temperatures (26°C and 30°C) significantly increased growth and production of juvenile largemouth bass compared with those reared at 20°C. However, feed training is typically practiced at ambient pond or well-water temperatures below 24°C. Increased culture temperatures could be important during the feed-training phase as it will likely influence appetite and starvation time. The objective of this research was to evaluate the effect of three water temperatures (20, 24, and 28°C) on feed-training success and growth of juvenile largemouth bass.

Methods

Approximately 2,000 pond-raised, northern strain largemouth bass fingerlings were obtained from the Pfeiffer Fish Hatchery in Frankfort, Kentucky. Baseline data were collected on 150 fish randomly sampled from a holding tank with a dip net then individually measured (TL) and weighed using an electronic

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TABLE 1.—Overall mean ± SD temperature, total ammonia-nitrogen, nitrite-nitrogen, total hardness, total alkalinity, dissolved oxygen, and pH from tanks maintained at three experimental water temperatures (21, 24, or 28°C) in which largemouth bass fingerlings were feed-trained in cages. Within rows, means with different letters are significantly different ($P < 0.01$).

	Experimental temperature		
Variable	21°C	24°C	28°C
Actual water temperature (°C)	21.0 ± 0.0 x	24.1 ± 0.1 y	28.1 ± 0.0 z
Ammonia-nitrogen (mg/L)	0.39 ± 0.13 y	0.44 ± 0.15 z	0.36 ± 0.13 y
Nitrite-nitrogen (mg/L)	0.09 ± 0.15 z	0.21 ± 0.27 z	0.18 ± 0.03 z
Hardness (mg/L)	153 ± 10 z	156 ± 28 z	144 ± 9 z
Alkalinity (mg/L)	96 ± 7 z	98 ± 4 z	101 ± 7 z
Dissolved oxygen (mg/L)	6.8 ± 0.7 z	6.4 ± 0.9 y	5.9 ± 0.7 x
pH	7.2 ± 0.1 z	7.2 ± 0.3 z	7.2 ± 0.3 z

balance (Ohaus Corporation, Pine Brook, New Jersey). The initial length was 5.6 ± 0.5 cm TL (mean ± SE) and the weight was 2.1 ± 0.6 g.

Largemouth bass fingerlings were stocked in rotation into twelve 0.5-m^3 polyethylene cages to achieve a stocking density of 350 fish per cage (700 fish/m^3). The cages were suspended in six 3,800-L polyethylene tanks (each tank containing two cages, two tanks per treatment temperature) housed in a greenhouse. After stocking, all treatments were initially maintained at 24°C for a 24-h conditioning period, and then gradually adjusted to target-treatment temperatures over a 24 h period. Tanks were maintained within 1°C of the target water temperatures throughout the duration of the experiment using heat pumps. Three water temperatures were evaluated (20, 24, and 28°C) with four replicate cages per treatment. Suitable water quality was maintained by a continuous daily water exchange of approximately 15% of the system volume with water from an outdoor reservoir pond. Since the two tanks run at each temperature shared the same water flow from a common heat pump, data were not blocked over the tanks, but analyzed as a completely random design.

In each cage, fingerlings were initially fed freeze-dried krill (FDK) then gradually weaned onto a 1.5-mm, commercial, floating pellet containing 45% protein and 12% fat (Steelhead Grower Formulation, Silver Cup, Inc., Murray, Utah) according to a schedule modified from Kubitza and Lovshin (1997). For days 1–3, fish were fed only FDK; for days 4–6 they were fed 75% FDK and 25% commercial diet (75:25 ratio); for days 7–9, a 50:50 ratio; for days 10–12, a 25:75 ratio; and then for days 13–24 they were fed only the commercial diet. This period was long enough to ensure that feeders and nonfeeders could be successfully differentiated. Fish were fed based on a percent of initial stock weight, which was adjusted to ensure that all cages were fed to slight excess. Initially the bass were fed a daily ration of 10% initial body weight per day (BW/d) divided into two equal feedings at 0900 and 1600 hours. On day 8, due to an increase in feed consumption, the daily ration was increased to 15% initial BW/d in all treatments.

Water temperature and dissolved oxygen (DO) were measured twice daily using a YSI 85 DO meter (YSI Co., Yellow Springs, Ohio). Total ammonia and nitrite were measured three times per week using a HACH DR/2500 spectrophotometer (HACH, Loveland, Colorado); pH was also measured at these times using a pH Tester 2 (HACH, Loveland, Colorado). Alkalinity and total hardness were measured once weekly using a HACH digital titrator (HACH, Loveland, Colorado).

At the conclusion of the experiment, all fish in each cage were removed, individually weighed, and measured for TL. To calculate the number of feed-trained fish in each cage, fish were fed in the morning of the harvest date and each fish was eviscerated within 1 h of feeding to document the presence or absence of feed in the gut.

Data were analyzed as a completely randomized design with analysis of variance (ANOVA) ($P \leq 0.05$) using Statistix version 8.0 (Statistix Analytical Software, Tallahassee, Florida). If significant treatment differences were indicated, treatment means were separated using Fisher's Least Significant Difference test (Steel and Torrie 1980). All percentage and ratio data were arcsine-transformed before analysis (Zar 1984).

Results

Temperatures were maintained within 1°C of target temperatures averaging (±SD) 21.0 ± 0.0, 24.1 ± 0.1, and 28.1 ± 0.0°C over the duration of the study period. Dissolved oxygen concentrations were significantly different ($P \leq 0.01$) among treatments (Table 1). Differences were primarily due to decreased solubility of oxygen at increasing temperatures (Boyd 1979). If oxygen concentrations are compared as a percent of saturation, all treatments averaged within 74–76%

TABLE 2.—Mean ± SD percent survival, percent feed-trained, individual weight (g), individual weight for feed-trained fish, individual TL (cm), and average individual TL (cm) for feed-trained juvenile largemouth bass after a 24-d feed-training period in cages suspended in tanks maintained at three water temperatures (21, 24, or 28°C). Within rows, means with different letters are significantly different ($P < 0.05$).

Variable	Water temperature		
	21°C	24°C	28°C
Survival (%)	98.1 ± 1.3 z	98.1 ± 0.5 z	97.4 ± 0.5 z
Feed-trained (%)	70.3 ± 4.5 x	82.4 ± 5.2 y	90.1 ± 5.2 z
Average weight (g)	4.8 ± 0.3 x	6.3 ± 0.4 y	7.5 ± 0.4 z
Average weight of feed-trained fish (g)	5.4 ± 0.3 x	6.8 ± 0.1 y	7.8 ± 0.2 z
Average TL (cm)	7.1 ± 0.3 z	7.6 ± 0.1 z	7.8 ± 0.2 z
Average TL of feed-trained fish (cm)	7.3 ± 0.1 z	7.8 ± 0.1 z	8.0 ± 0.1 z

saturation. Overall average total ammonia-nitrogen concentrations were significantly higher ($P \leq 0.01$) in the 24°C treatment tanks compared with other treatments (Table 1), although the concentrations and differences were not considered to be biologically significant. Water quality over the course of the experiment was considered suitable for largemouth bass growth and survival.

Survival of largemouth bass averaged 98% among treatments and no significant differences ($P \geq 0.05$) existed (Table 2). Average fish weight and percentage of feed trained fish were significantly different among all three temperatures ($P \leq 0.05$) and increased with increasing water temperature. The percentage of fish successfully feed trained averaged 70, 82, and 90% for the 21, 24, and 28°C treatments, respectively (Table 2). Individual weights averaged 5.4, 6.8, and 7.8 g for fish feed trained at 21, 24, and 28°C, respectively (Table 2).

Discussion

Water temperature has a significant influence on feed-training success and growth rate of largemouth bass fingerlings during the feed-training phase. Juveniles habituated to commercial diets more readily at 28°C than at 24°C, with the middle temperature group performing better than those at the lower temperature. Cox and Coutant (1981) studied feed consumption of juvenile striped bass *Morone saxatilis* with satiation feeding at different temperatures and found that food intake increased as water temperature increased from 16 to 24°C and then reached a plateau before decreasing above 30°C. Tidwell et al. (2003) found advanced largemouth bass fingerlings grew better at 26°C, but survival was reduced at 30°C. Given that increasing water temperature increases the energy demand for maintenance and activity of fish (Weatherley and Gill 1987), at some point further increases will not be productive. However, it is unknown whether higher temperatures than those evaluated in this study would be beneficial or detrimental during feed training of largemouth bass.

Training success in this study was 70–90%, which is higher than many published reports, but is comparable with previous feed-training experiments at this laboratory using the same strain, similar-sized fish, and a floating pellet as the training diet (Skudlarek et al. 2007). According to Heidinger (2000), most established producers of largemouth bass are successful in training approximately 75% of pond-reared fingerlings to feed on a prepared diet. It is not known whether the increased percentage of feed-trained fingerlings that could be produced by increasing water temperatures would justify the increased cost associated with heating water, as economics would vary by economies of scale and the source and cost of heating. Clearly, additional work is needed to provide a greater understanding of the physiology of largemouth bass during the feed-training phase and to determine the individual factors that contribute to success.

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