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COMMUNICATIONS

Overwintering Yellow Perch Fry in Alabama

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Abstract.—Wild harvests of yellow perch *Perca flavescens* have failed to keep up with the strong market demand for the fish. Moreover, yellow perch has many attributes that make it attractive for commercial aquaculture in the USA. One drawback to yellow perch culture in the north-central region of the United States is that low winter water temperatures inhibit somatic growth. In this study, yellow perch juveniles were stocked at three densities (30, 60, and 90 per tank) in 600-L tanks in Auburn, Alabama, in early January and maintained throughout the winter until mid-April. Water in the tanks was circulated through an earthen pond and returned to the research system by means of a water pump. Tanks were aerated by means of submersible air diffusers and a regenerative air blower. Fish were offered a commercial, slow-sinking feed at 5% of body weight, and temperature was measured hourly by a remote data logger. Survival was greater than 99% in all treatments. When water temperature was below 20°C, absolute growth was 0.06, 0.05, and 0.04 g/d for the low-, medium-, and high-stocking density treatments, respectively. When water temperature was above 20°C, absolute growth was 0.58, 0.48, and 0.46 g/d for the low-, medium-, and high-stocking density treatments, respectively. Yellow perch juveniles survived well and grew well in Alabama during fall and spring seasons when temperatures were above 20°C.

The yellow perch *Perca flavescens* has many attributes that make it attractive for commercial aquaculture in the USA (Heidinger and Kayes 1986). The market demand for yellow perch is strong, reflecting consumer preference for aquatic food products derived from this fish (Lesser and Vilstrup 1979). Moreover, commercial harvests due to stock declines and regulatory constraints have failed to keep up with the strong demand (see Lesser and Vilstrup 1979; Belonger 1986). The failure of wild harvests to meet demand thus created an interest in yellow perch aquaculture (Downs and Smith 1983).

The main market for yellow perch in the United States is in the north-central region, with consumption in Wisconsin accounting for 75% of wild-caught fish (Heidinger and Kayes 1986). Consequently, an emerging aquaculture industry for the fish is developing in the north-central region (Heidinger and Kayes 1986). Unfortunately, the temperature in Wisconsin is not conducive to the year-round culture of yellow perch. Optimal temperatures reported in the literature vary among researchers but range between 22°C and 28°C, with a range of tolerance from freezing to 33°C (Calbert and Huh 1976; Kitchell et al. 1977; Heidinger and Kayes 1986; Tidwell et al. 1999; Brown et al. 2002). Heidinger and Kayes (1986) suggest that in the north-central states, fish raised in ponds on natural food require 2–3 years to reach a marketable size of 20 cm (150 g). However, a model developed by Kitchell et al. (1977) predicts a growing season of only 15–18 months, including winter for fish fed ad libitum. Although bioenergetics models are an important and necessary tool in modern-day research, they do not always duplicate empirical results. Calbert and Huh (1976) suggested that 1.0–1.5-g yellow perch will reach market size in 9–11 months when temperature is maintained at 21°C. Henderson et al. (2000) reported that yellow perch growth in Lake Erie was greatest during the summer and lowest in winter.

Another factor affecting fish growth is stocking density. Density could affect water quality, survival, growth, size variation, feed conversion, and predation (see Bromage et al. 1988; Malison and Held 1992; Hecht and Pienaar 1993). Various authors report stocking densities of yellow perch fingerlings between 20,000 and 150,000 fish/ha depending on the size of stocked fish, the length of the culture period, and the final harvest weight of the fish (e.g., Buttner 1989; Malison and Held 1992; Riepe 1997). However, since yellow perch survival varies significantly from facility to facility (Head and Malison 2000) and is affected by outside disturbances (Malison and Held 1992), op-

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timal rearing densities for individual production facilities, or at least regions, should be investigated.

In the present experiment, we evaluated yellow perch survival and growth at three different densities in outdoor tanks in Alabama. Since winter temperatures in Alabama are warmer than in the north-central states, we explored the idea of overwintering yellow perch in Alabama and transporting the subadults to the north-central region farms for grow out during the warm summer months when temperatures in Alabama rise beyond optimal limits for yellow perch.

Methods

The present work was performed at the North Auburn Fisheries Station (NAFS) in Alabama. Yellow perch fingerlings were trained to take artificial feed at a commercial hatchery in South Carolina, size graded (to remove large fish and runts), and transported to a quarantine tank in NAFS on January 5, 2003. The fish were held in quarantine for 10 d and maintained on an extruded, slow-sinking feed (40% protein; Silver Cup Trout, Nelson and Sons, Inc., Murray, Utah).

The research system consisted of twenty-seven 600-L round tanks (diameter = 115 cm; height ≈ 60 cm) supplied with water from a 400-m^2, 1.5-m-deep earthen pond. Each tank was aerated using two submerged air diffusers. Water was pumped from the pond into the tanks and drained back to the pond. The water flow rate in each tank was 2,400 L/d. On January 15, 2003, four random samples of at least 30 fish were taken and weighed to calculate the average weight per fish. The remaining fish (average weight = 6.05 g) were stocked into the round tanks at three densities (30, 60, and 90 fish per tank), with nine replicate tanks per treatment. Three-hundred fish were maintained in a separate 600-L tank and fed ad libitum. A remote temperature logger (HOBO, Onset Computer Corp., Bourne, Massachusetts) was submerged in one of the tanks and recorded temperature hourly for the duration of the experiment. Fish were offered extruded, slow-sinking feed (40% protein; Silver Cup Trout) at 5% of their weight at stocking until March 27, when ambient water temperature rose to 20°C. On March 28, the fish were harvested, counted, weighed, and returned to their respective tanks. Missing fish were replaced with fish from the spare tank. Ration was increased to 5% of the new fish biomass per tank.

The experiment was terminated on April 19, due to an overabundance of filamentous algae in the tanks. Fish were harvested, counted, and group weighed. Fish from three replicates tanks in each treatment were individually weighed and measured, and feed efficiency (FE) was calculated (FE = [weight gain/weight of feed offered] × 100).

The coefficient of variation (CV) of final fish weights was calculated as

$$\text{CV} = \text{SD/mean}.$$

The relative condition factor (K_n) described by Le Cren (1951) was calculated as

$$K_n = (W/W') \times 100,$$

where W is the weight of the individual fish and W' is the predicted length-specific mean weight for a fish in the population under study. The form of the weight–length equation used to determine (W') was

$$\log_{10}(W') = a' + b \times \log_{10}(L_T),$$

where a' is the intercept value, b is the slope of the $\log_{10}$(weight)–$\log_{10}$(length) regression equation, and (L_T) is the total length of individual fish (Anderson and Neumann 1996).

Finally, the absolute growth (AG; Hopkins 1992) of the fish for the first 71 d and the last 23 d of culture was calculated as

$$\text{AG} = (\text{FBW—IBW})/D,$$

where FBW is the final body weight, IBW is the initial body weight, and D is the number of days.

Statistical analyses were conducted with SAS for Windows (SAS Institute 2000). Initial weight, final weight, final length, percent weight gain, percent survival, FE, CV of final weights, and K_n were analyzed by means of one-way analysis of variance (ANOVA) to determine whether significant ($P <$ 0.05) differences were present among treatment means. Treatment means were compared using a Student–Newman–Keuls multiple-range test. Regression analyses were used to describe effects of density on the dependant variables (survival, final weight, K_n, growth, and FE).

Results and Discussion

The survival of yellow perch in the present experiment was greater than 99% at all stocking densities evaluated (Table 1). These results agree with the reported survival of 98% for yellow perch longer than 31 mm by Heidinger and Kayes (1986). Temperatures encountered by the fish during the study (Figure 1) did not appear to affect survival.

TABLE 1.—Survival, weight, condition index (K_n), and coefficient of variation (CV = SD/mean) of yellow perch (mean initial weight = 6.05 g) stocked at three densities in 600-L round tanks. The period between stocking and first sampling was 71 d and that between first sampling and final harvest 23 d. Values in the same column with different letters are statistically different from one another ($P < 0.05$).

Density (fish / tank)	First sampling: Survival (%)	First sampling: Weight (g)	Final Harvest: Survival (%)	Final Harvest: Final weight (g)	K_n	CV	FE[a]
Low (30)	99.9	10.4 z	99.3	23.2 z	1	0.47	94.4 z
Medium (60)	99.9	9.6 y	99.6	20.7 y	1	0.5	88.7 y
High (90)	99	8.7 x	99.8	19.2 x	1	0.47	74.4 x
PSE[b]	0.46	0.25	0.32	0.32	0	0.016	0.32
P	0.31	0.002	0.62	<0.0001		0.63	<0.001

[a] FE = feed efficiency, calculated as (weight gain/weight of feed offered) × 100.
[b] PSE = pooled standard error.

There was no difference in fish survival at temperatures below 20°C and temperatures greater than 20°C.

Stocking density had a significant effect on growth rate at both temperature ranges chosen for the present study. The perch stocked at 30 per tank grew faster than the fish stocked at 60 per tank which, in turn, grew faster than the fish stocked at 90 per tank (Table 1). Covariant analysis using density and initial weight as the covariants during the second phase of the experiment show that there is no effect of initial weight on final weight ($P > 0.8$). Stocking density also had an effect on feed efficiency, where the FE of fish stocked at 30 per tank was 94.4, significantly greater than the FE at 60 and 90 per tank, which were 88.7 and 74.4, respectively (Table 1). However, stocking density did not have an effect on the condition index of the fish nor on the CV in size among treatments. These results do not mean that stocking density does not affect growth depensation. Growth depensation among graded fish is dependant on several factors, including feed regimen, water temperature, and species as well as stocking density (see Brown 1946, 1957; Jobling and Wandsvik 1983; Koeble 1985). Furthermore, enough culture time at specific environmental conditions has to be allowed for prior to observing variation in growth. Nonetheless, our results suggest that yellow perch are communal fish that could be held at greater densities than suggested in the literature if offered enough feed and if water quality is kept within acceptable ranges.

Temperature had a significant effect on growth rate. The AG when temperature was less than 20°C averaged 0.05 ± 0.01 g/d (mean ± SD), significantly less than the average AG when the temperature was more than 20°C, 0.50 ± 0.07 g/d ($P < 0.0001$; Table

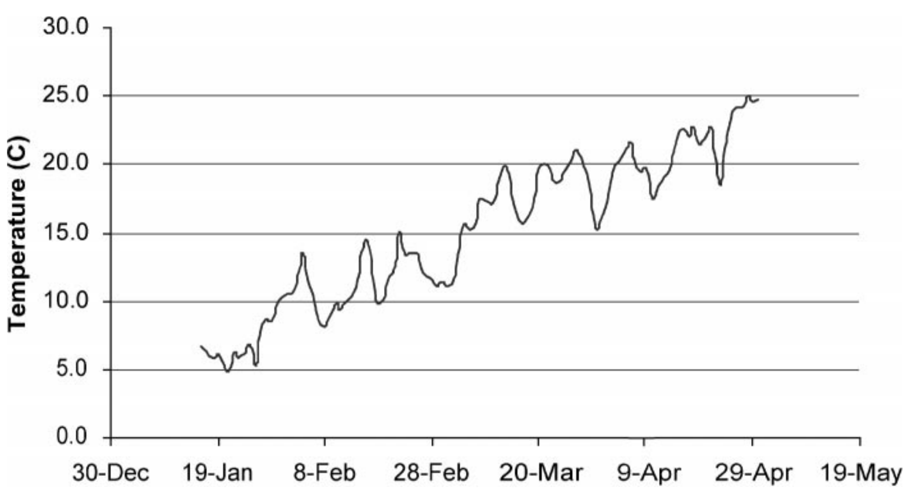

FIGURE 1.—Average daily pond water temperature in Auburn, Alabama, between January 15, 2003, and April 30, 2003.

TABLE 2.—Absolute growth (g/d) of yellow perch stocked at three densities in 600-L round tanks during two growth periods. The mean initial weight for the first period was 6.05 g and that for the second period 10.44, 9.58, and 8.68 g for the low-, medium-, and high-density treatments, respectively. Values in the same column with different letters are significantly different from each other ($P < 0.05$).

Density (fish/tank)	AG[a], 71 d, (T[b] < 20°C)	AG, 23 d, (T > 20°C)
Low (30)	0.06 z	0.58 z
Medium (60)	0.05 y	0.48 y
High (90)	0.04 x	0.46 y
Average	0.05	0.50
P	<0.001	<0.001

[a] AG = absolute growth.
[b] T = temperature.

2). Optimal temperatures reported in the literature range between 22°C and 28°C (Calbert and Huh 1976; Kitchell et al. 1977; Heidinger and Kayes 1986; Tidwell et al. 1999; Brown et al. 2002). Such results suggest that winter temperatures in Alabama are more conducive to yellow perch growth than in Wisconsin. Water temperature in the pond used for the present study did not drop below 4.5°C during the winter of 2003, and temperatures started rising above 20°C as early as March 27. Temperatures in central Wisconsin did not rise to 20°C until late June (Wisconsin–Minnesota Cooperative Extension Agricultural Weather; www.soils.wisc.edu/wimnext/weather.html). Ponds in Wisconsin are usually covered with ice from January through March 15, and temperature rises to circa 10°C around the end of April (J. Malison, University of Wisconsin, personal communication). These environmental conditions shorten the growing season in north-central states. Malison et al. (1988) report that under optimal conditions, perch could reach 10–40 g in their first growing season. Therefore, Wisconsin farmers would require two to three seasons for their perch to reach a market size of 150 g. If perch fingerlings are overwintered in Alabama then shipped to Wisconsin in June for grow out, they might reach market size in 1 year.

Aquaculturists in the southern states who raise tropical and temperate species usually have fallow ponds during winter months. Most tropical and temperate species (such as tilapia and penaeid shrimp) require temperatures in excess of 26°C to perform well. It would be possible for farmers to harvest their ponds in September or October and stock yellow perch fingerlings in November once temperatures are below 28°C. Then, in the spring, farmers would harvest the advanced fingerlings and ship them to the north-central region for grow out. The results of the present study suggest that the fish would grow well in the late fall as well as in early spring, when growth in the north-central region is slow. Moreover, catfish farmers could use a setup such as the one used in the present experiment to maintain yellow perch in water pumped from catfish ponds.

Yellow perch are native to some Alabama rivers (Smith-Vaniz 1968), and farmers would not be introducing an exotic species if they brought fingerlings from the north-central states. The present study demonstrates that yellow perch fingerlings survive and grow during the winter months. Accordingly, we see no impediment to a perch culture industry being developed. With further research on culture requirements (such as stocking densities, feeds, feeding regimens, and transportation protocols), an industry could be successfully introduced.

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