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Effects of Stocking Size and Density on Winter Trout Culture in Cages in Kentucky

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ABSTRACT

Production of rainbow trout (*Salmo gairdneri*) in cages was evaluated for use in aquacultural double cropping in Kentucky. Trout production in cages with 15-cm and 20-cm fingerlings at densities of 320/m³, 480/m³, 640/m³ and 960/m³ indicated best production performance with 20-cm fingerlings at densities of 320/m³ and 640/m³. Mean harvest weights were 187–198 g for these treatments. Survival was 91.6–98.6% for all treatments tested. Trout may provide winter fish culture opportunities for Kentucky farmers.

INTRODUCTION

Rainbow trout have been examined as a suitable winter species for aquacultural double cropping in many southern states. Early studies in Alabama (1, 2), Louisiana (3) and Mississippi (4) evaluated the feasibility of producing rainbow trout in static water ponds with variable success. Problems encountered were poor fish survival and feed conversion and significant growth variability. Later pond and cage culture studies by Newton (5), Jensen (6), Flynn (7) and Hansen (8) demonstrated improved production feasibility, although limited duration of the southern winter growing season and poor feed conversions continued to negatively affect economic viability, particularly for cage culture.

Meteorological records for Kentucky indicate a production season of sufficient duration (180–200 days) for producing marketable trout, depending on the severity of winter temperatures. The objectives of these studies were to evaluate the feasibility of culturing rainbow trout in cages for use in aquacultural double cropping in Kentucky and to examine various stocking densities, stocking sizes and feed rations.

MATERIALS AND METHODS

Rainbow trout production studies were conducted over a 2-year period from November 1983 to May 1985. In 1983, 51-g and 82-g trout fingerlings were stocked in 1.25-m³ floating cages at densities of 640 and 960 fish per m³. Fish were purchased from a raceway trout producer in Kentucky and had been pre-graded into approximately 15-cm and 20-cm size groups. Cages were constructed of 1.3-cm extruded plastic screen attached to 1.2-m galvanized steel hoops and floated with 15-cm-diameter PVC sponge floats. Cages were cylindrical and were 1.2 m in diameter and depth. Cages were anchored individually in deep water with concrete blocks and randomly positioned by treatment groups in a 1.8-ha farm pond. Fish were fed a 40% protein sinking trout food twice daily, 7 days per week, weather and ice conditions permitting. Rations were given as a percentage of body weight based on water temperature and fish size (Table 1). Fish weight was adjusted weekly based on an assumed feed conversion rate of 1.5 and readjusted after monthly samplings for fish growth. Duration of the study was 184 days, from 5 November 1983 to 6 May 1984. At the end of the study all fish were weighed and approximately 25% of the fish in each cage counted to compute mean fish weight.

In 1984, 50-g trout fingerlings were stocked in 1.25-m³ floating cages at a density of 320 fish per m³, and 94-g trout fingerlings were stocked in 1.25-m³ floating cages at densities of 320, 480 and 640 fish per m³. Fish were purchased from raceway trout producers in Kentucky and had been pre-graded into approximately 15-cm and 20-cm size groups. Cages were those used in the 1983 study. Cages were secured to a 1.2-m × 19.5-m floating pier anchored offshore in a 1.18-ha farm pond. Treatment replications were randomly as-

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TABLE 1. Daily feeding rates for rainbow trout in cages, Frankfort, Kentucky. Feed quantity was computed as a percentage of fish body weight in correlation with fish size and water temperature.

Fish weight (g)	Fish size (cm)	Water temperature (°C)						
		4.4–7.2	7.8–8.9	9.4–10.6	11.1–12.2	12.8–13.9	14.4–15.6	16.1–17.2
		Per cent body weight per day						
45	15.2	1.6	1.9	2.1	2.3	2.4	2.5	2.8
57	17.2	1.5	1.7	1.9	2.2	2.3	2.4	2.7
65	17.8	1.4	1.7	1.8	2.1	2.2	2.3	2.6
76	18.4	1.3	1.6	1.7	2.0	2.1	2.2	2.5
91	19.1	1.2	1.5	1.6	1.8	1.9	2.0	2.3
113	21.0	1.1	1.4	1.5	1.7	1.8	1.0	2.2
151	24.1	1.0	1.3	1.4	1.6	1.7	1.8	2.0
227	26.7	0.9	1.2	1.3	1.5	1.6	1.7	1.8
454	33.0	0.9	1.0	1.2	1.3	1.4	1.5	1.6

signed around the perimeter of the pier. Fish of both sizes and at all densities were fed a 40% protein sinking trout feed twice daily, 7 days per week, weather and ice conditions permitting. Rations were given as a percentage of body weight based on water temperature and fish size (Table 1). In addition, 1 treatment of 94-g fish at the $320/m^3$ density was fed a 40% floating trout feed on the same regime as those receiving the sinking feed. Fish weight was adjusted every 2 weeks based on assumed feed conversion rate and readjusted after monthly fish samplings. Duration of the study was 171 days, from 2 November 1984 to 21 April 1985. At the end of the study all fish were weighed, counted and sorted by size. Fish were sorted into small, medium and large categories with 1.90-cm and 2.45-cm aluminum bar graders.

Trout stocked in cages in 1985 were diagnosed shortly after stocking to be infected with *Yersinia ruckeri* (Enteric Redmouth Disease—ERM). Fish were placed on a medicated feed for 15 days post-stocking; however, significant fish losses occurred during the first 4 weeks post-stocking. Fish lost during this period were replaced with fish of equal size and the study restarted on 28 November 1985.

RESULTS

Cage Culture Production

1984

In 1984, the best performance was obtained by the 20-cm fingerling group at a density of 640 per m^3, with a mean harvest weight of 198 g. Net gain for this group was 116 g per fish, or approximately 0.63 g per day. Fish were fed 295 of 368 scheduled feedings during the 184-day production period. Cancelled feedings resulted from low water temperature and/or adverse ice conditions.

Density was a significant factor in growth for both size groups. There was a significant difference ($P < 0.05$) in mean harvest weight of 15-cm fingerlings reared at densities of 640 and 960 per m^3, with the lower density outperforming the higher density by 24% (161 g vs. 129 g) (Table 2). There was also a significant difference ($P < 0.05$) in the mean harvest weight of 20-cm fingerlings at the same densities, with the lower density outperforming the higher density by 15% (198 g vs. 172 g) (Table 2). There were significant differences ($P < 0.05$) in 15-cm and 20-cm groups stocked at the same densities, with the larger size group significantly outperforming the smaller group at both densities tested (Table 2). There was no significant difference, however, in mean harvest weight between the low density ($640/m^3$) 15-cm group and the high density ($960/m^3$) 20-cm group.

Net production per cage averaged 88.7 kg for all treatments. There were no significant differences in net production among any of the treatments (Table 2). Feed conversion ratio was poor for all treatments and ranged from 2.3:1 to 3.4:1 (Table 2). There was a direct correlation between feed conversion and density, with the lower stocking densities of both cm groups having significantly better feed conversions than their corresponding higher density groups. The lowest feed conversion ratio was 2.3:1 for the 15-cm × $640/m^3$ treatment, though this was not significantly different from the conversion ratio of 2.5:1 for the 20-cm × $640/m^3$ treatment. Survival ranged from 91.6%

TABLE 2. Summary of rainbow trout production performance in 1.25-m^3 floating cages for winter of 1983/1984, Frankfort, Kentucky.[1]

Treatment (fish/m^3)	Mean harvest weight (g)	Gross production (kg)	Net production (kg)	FCR[2]	Per cent survival
640 × 15 cm	161 b	125.4 a	81.8 a	2.3:1 a	97.4 b
960 × 15 cm	129 a	150.9 b	92.4 a	2.8:1 b	97.1 b
640 × 20 cm	198 c	153.2 b	88.9 a	2.5:1 a,b	96.6 b
960 × 20 cm	172 b	189.9 c	91.7 a	3.4:1 c	91.6 a

[1] Column figures followed by same letter are not significantly different ($P > 0.05$).
[2] Feed conversion ratio.

to 97.4% (Table 2). Survival was poorest in the 20-cm × 960/m^3 treatment and was significantly different from all other treatments.

1985

In 1985, best performance was obtained by the 20-cm fingerling groups stocked at 320 fish/m^3. Floating and sinking feed treatments with this size-density group had mean harvest weights of 191 g and 187 g, respectively. Net gains for these treatments were 97 g and 94 g per fish, respectively, or approximately 0.55 g per day. Fish were fed 260 of 342 scheduled feedings during the 171-day production period; cancelled feedings resulted from low water temperature and/or adverse ice conditions. Density had a significant effect upon mean harvest weight, with 20-cm fish at the 320/m^3 density outperforming fish at the 480/m^3 and 640/m^3 densities (Table 3). There were no differences in mean harvest weight between the 480/m^3 and 640/m^3 densities. As in 1984, 20-cm fish at all densities tested significantly outperformed 15-cm fish tested.

Net cage production per treatment ranged from 28.7 kg to 41.4 kg, with a per cage average of 34.2 kg for all treatments (Table 3). Net production was significantly different ($P < 0.05$) between the 15-cm × 320/m^3 and 20-cm × 320/m^3 sinking feed treatments and all other treatments (Table 3). There were no differences in net production between the 320/m^3 float, 480/m^3 and 640/m^3 treatments.

Feed conversion ratio was poor for all treatments, ranging from 2.3:1 to 4.4:1 (Table 3). Best feed conversion was obtained by the 15-cm group at the 320/m^3 density. Although weight gain was not significantly different between fish fed floating and sinking feeds at the 320/m^3 density, feed conversion ratio was significantly better with the floating feed (2.5:1 vs. 3.4:1). There was no difference in feed conversion between the 320/m^3 and the 480/m^3 treatments fed sinking feed. Poorest feed conversion was obtained at the 640/m^3 density with 20-cm fish. Mean survival for all treatments was 95.7%. Survival ranged from 94.1% to 98.6%, with no significant differences between treatments (Table 3).

Highest percentage of large fish at harvest was obtained in the lowest density treatments with the 20-cm size group. Yields were approximately 70% and 67% large fish, respectively, for the sinking and floating feed treatments at the 320/m^3 density with 20-cm fish (Table 4). At the 480/m^3 and 640/m^3 densities with 20-cm fish, only 41% and 56% of the fish graded into the large category, respectively. Small, runt fish composed a small proportion of the harvest in all treatments (Table 4). Grad-

TABLE 3. Summary of rainbow trout production performance in 1.25-m^3 floating cages for winter of 1984/1985, Frankfort, Kentucky.[1]

Treatment (fish/m^3)	Mean harvest weight (g)	Gross production (kg)	Net production (kg)	FCR[2]	Per cent survival
320 × 15 cm, sink	123 a	48.6 a	28.7 a	2.3:1 a	98.6 a
320 × 20 cm, sink	187 c	70.8 b	29.3 a	3.4:1 b	95.0 a
320 × 20 cm, float	191 c	73.7 b,c	37.1 b	2.5:1 a	96.5 a
480 × 20 cm, sink	152 b	85.9 c	35.8 b	3.4:1 b	94.1 a
640 × 20 cm, sink	161 b	121.7 d	41.4 b	4.4:1 c	94.3 a

[1] Column figures followed by same letter are not significantly different ($P > 0.05$).
[2] Feed conversion ratio.

TABLE 4. Percentages of small, medium and large rainbow trout harvested from varying production treatments in 1.25-m^3 floating cages in 1985, Frankfort, Kentucky. Fish were sorted into size categories with 48/64 and 62/64 aluminum bar graders.[1]

Treatment (fish/m^3)	Per cent fish by size category		
	Small (53 g)	Medium (129 g)	Large (195 g)
$320/m^3$ × 15 cm, sink	3.3 c	88.2 c	8.5 a
$320/m^3$ × 20 cm, sink	0.6 b	29.2 a	70.2 c
$320/m^3$ × 20 cm, float	0.0 a	32.6 a	67.4 c
$480/m^3$ × 20 cm, sink	1.5 b	57.6 b	40.9 b
$640/m^3$ × 20 cm, sink	1.3 b	42.6 a	56.1 c

[1] Column figures followed by same letter are not significantly different ($P > 0.05$).

ed fish averaged 53 g for the small category, 129 g for the medium category and 195 g for the large category.

Production performance of caged fish in all 1985 cage studies was adversely affected by chronic infection with *Yersinia ruckeri* bacteria. Caged trout were treated with medicated feed for 10–15-day intervals on 2 occasions to control ERM. ERM infection may have accentuated density effects, with higher density treatments responding more negatively to the infection.

DISCUSSION

Comparison of trout production performance in cages at all densities and size groups tested in a 2-year period indicated that fingerlings 20 cm or larger are required for stocking cages. Growth performance of 20-cm fish at densities of $320/m^3$, $480/m^3$, $640/m^3$ and $960/m^3$ indicated best overall mean harvest weight at the $640/m^3$ density (198 g). Growth performance at this density, however, was not significantly different ($P > 0.05$) from growth performance of 2 treatments at the $320/m^3$ density (191 g and 187 g). It is probable that production performance in the 1985 study was significantly affected by chronic bacterial problems and that trout growth and feed conversion at the lower densities tested in 1985 could have been better with healthier fish. Overall results indicate production of rainbow trout in cages in farm ponds in Kentucky is feasible, although there is a need to significantly improve feed conversion.

Most rainbow trout produced in the U.S. are grown in raceway systems supplied with constant water temperature. Most commercial diets are formulated for this type of system. In a static system such as cages in ponds, there is wide fluctuation in water temperatures throughout the winter growing season. A different diet formulation may be required for improving feed conversion and growth in a system experiencing temperature fluctuations. Takeuchi et al. (9) found by increasing protein and lipid levels up to a maximum of 35 per cent protein diets and 15–20 per cent lipid, feed conversion and weight gain improved. Some feed companies (pers. comm., Dr. Thomas Ziegler, President of Ziegler, Gardner, PA) recommend a high energy, fast growing ration for trout culture in a wide range of water temperatures, for best results.

Further improvement in fish harvest weight can be obtained. It is probable that fall water temperatures will permit stocking trout in cages in early to mid-October in Kentucky. This would extend the production season by 20–30 days over that tested. Refinements in feeding methodologies (per cent body weight feeding, demand feeding, etc.) should also improve fish growth and feed conversion.

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