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Research Article

Use of Vertically-Suspended Environmental Enrichment during Early Rainbow Trout Rearing

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Abstract

This study evaluated the use of vertically-suspended structure as a form of environmental enrichment during hatchery rearing of rainbow trout *Oncorhynchus mykiss*. This experiment was broken up into two rearing periods, with fish remaining in the same treatment throughout the study. The first period began with initial feeding and lasted for 48 days. The second commenced immediately after the first and lasted for 132 days. At the end of the first period, final tank weight, gain, and feed conversion ratio were not significantly different between the tanks of fish with or without vertically-suspended structure. At the end of the second period, final tank weight and gain were significantly greater in tanks with vertically-suspended environmental enrichment compared to the unenriched control tanks. Condition factor was also significantly higher in the fish reared with structure. The results of this study indicate that vertically-suspended environmental enrichment use is not harmful during the period of rainbow trout initial feeding and positive impacts on growth occur at the later stages of juvenile rearing.

Keywords: Rainbow trout; *Oncorhynchus mykiss*; Environmental enrichment; Vertically suspended structure

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Introduction

The effects of enriching typically sterile hatchery rearing units have been investigated with many species of fish [1-3]. Environmental enrichment research has focused on salmonids and has generally increased fish growth [4-6], post-stocking survival [7,8], and natural behaviors [3,9-11].

One form of environmental enrichment is physical enrichment, which typically involves adding structural complexity to hatchery rearing tanks. Initial attempts to add materials into circular tanks frequently interfered with hydraulic self-cleaning, resulting in increased labor demands and disease risks [2,12-16] solved this conundrum by developing vertically-suspended structure. This enrichment maintained circular tank self-cleaning, and significantly improved rainbow trout *Oncorhynchus mykiss* growth and feed conversion ratio. Subsequent investigations have confirmed the benefits of using vertically-suspended arrays during juvenile salmonid rearing [15,17-22].

Despite the plethora of physical enrichment research during hatchery rearing, [2,12,16,23,24], only one study has been conducting on fish during initial feeding. Huysman et al. [25] investigated vertically-suspended environmental enrichment during the initial feeding of Chinook salmon Oncorhynchus tshawytscha. Thus, the objective of this experiment was to evaluate the effects of vertically-suspended environmental enrichment on rainbow trout growth, beginning at initial feeding and continuing during an extended period.

Methods

This experiment was conducted at McNenny State Fish Hatchery, Spearfish, South Dakota, USA, using degassed and aerated well water at a constant temperature of 11°C (total hardness as $CaCO_3$, 360 mg L^{-1}; alkalinity as $CaCO_3$¬, 210 mg L^{-1}; pH, 7.6; total dissolved solids, 390 mg L^{-1}). The circular tanks (1.8 m in diameter, 0.8 m deep, 0.6 m operating depth) used in this study were near fully covered [26] and contained Erwin-Arlee strain rainbow trout. The experimental design consisted of barren control tanks and tanks containing an array of four vertically-suspended aluminum angles as described by Krebs, et al. [15] as environmental enrichment. The angles were arranged so that the angled portion faced into the direction of water flow (**Figure 1**).

This experiment was separated into two sequential rearing periods. The first period began at initial feeding on November 2, 2018 and ended on December 19, 2018, resulting in duration of 48 days. Approximately 5,000 (1.4 kg) rainbow trout (mean ± SE weight 0.28 ± 0.01 g and total length 32.04 ± 0.35 mm, n=30) from a common pool were placed into each of six tanks (n=3). Fish were fed every 20 min during daylight hours using automatic feeders. Feeding rates were determined using the hatchery constant method [27], with an expected feed conversion ratio of 1.1 and a projected growth rate of 0.08 cm d^{-1}, a rate at or slightly above satiation. Fish were fed starter granules (Starter Crumble, Skretting USA, Tooele, Utah, USA). At the end of the period, total tank weights were obtained by weighing all the fish in a tank the nearest 0.1 kg. In addition, 10 fish from each tank were individually weighed to the nearest 0.1 g, and measured (total length) to the nearest 0.01 mm.

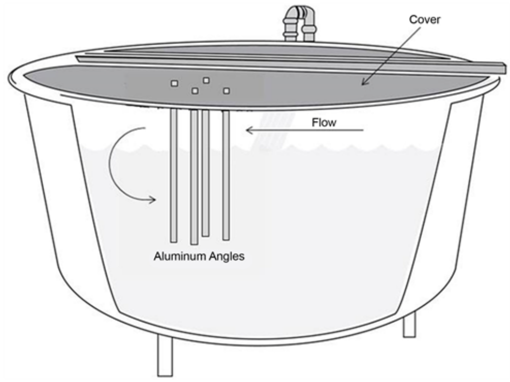

Figure 1. *Circular tank with suspended array of four aluminum angles, with the peak of the angle facing in the direction of the water flow.*

The second period commenced immediately after the first on December 20, 2018 and ended on April 30, 2019, for a duration of 132 days. The trout from each treatment (control or enriched) were pooled on December 19, 2018 and then placed back into three tanks per group (n=3). Fish remained in the same treatment for both periods. To maintain approximately the same number of fish per tank (2.500) at the start of the second period, the unenriched and enriched tanks received 6.4 kg and 6.7 kg of fish per tank, respectively. The tanks containing the enriched fish received a small increase in the amount of food compared to the control tanks because of the slightly heavier initial loading. Fish were fed 1.5 mm pellets (Protec, Skretting USA, Tooele, Utah, USA). Feeding rates were identical to the first period, as was data collection at the end of the period.

The following formulas were used:

- Gain=end weight-start weight
- Percent gain (%)=gain/start weight
- Feed conversion ratio=food fed/gain
- Specific Growth Rate(SGR)=100 × (ln(end weight)-ln(start weight))/number of days
- Condition factor (K)=10^5 × fish weight/fish length^3

Data were analyzed using the SPSS (24.0) statistical program (SPSS, Armonk, New York, USA), with significance predetermined at p <0.10. T-tests were used for mean comparisons.

Results

At the end of first period, there were no significant differences in final tank weight, gain, or feed conversion ratio between the control and environmental enrichment treatment (Table 1). Individual fish length, weight, and condition factor were also not significantly different (Table 2).

Table 1: *Duration, initial tank weight, mean (± SE) final tank weight, gain, food fed, and feed conversion ratio (FCR1) for rainbow trout reared with (enriched) or without (unenriched) environmental enrichment (period 1 is from initial feeding through day 48 and period 2 is rearing days 49-181). Means in a row with different letters are significantly different (p<0.1, n=3).*

	Parameters	Unenriched	Enriched
Period 1	Duration (days)	48	48
	Initial weight (kg)	1.4	1.4
	Final weight (kg)	13.0 ± 0.6	14.0 ± 0.3
	Gain (kg)	11.7 ± 0.6	12.6 ± 0.3
	Food fed (kg)	8.9	8.9
	FCR	0.76 ± 0.04	0.70 ± 0.01
Period 2	Duration (days)	132	132
	Initial weight (kg)	6.4	6.7
	Final weight (kg)	117.4 ± 3.3 z	128.0 ± 2.9 y
	Gain (kg)	110.7 ± 3.3 z	121.3 ± 2.9 y
	Food fed (kg)	132.2	134.6
	FCR	1.19 ± 0.04	1.11 ± 0.03

*Feed Conversion Ratio (FCR)=food fed/gain

Table 2: *Mean (± SE) individual total length, weight, specific growth rate (SGR1), and condition factor (K2) for rainbow trout with (enriched) or without (unenriched) environmental enrichment (period 1 is from initial feeding through rearing day 48, period 2 is rearing days 49-181). Means in a row with different letters are significantly different (p<0.10; n=3).*

	Parameters	Unenriched	Enriched
Period 1	Length (mm)	60.1 ± 1.9	62.6 ± 0.9
	Weight (g)	2.45 ± 0.2	2.77 ± 0.1
	SGR	4.5 ± 0.2	4.8 ± 0.1
	K	1.12 ± 0.02	1.13 ± 0.01
Period 2	Length (mm)	163.6 ± 8.2	175.4 ± 3.8
	Weight (g)	51.2 ± 8.8	65.2 ± 4.4
	SGR	2.3 ± 0.1	2.4 ± 0.1
	K	1.15 ± 0.02 z	1.21 ± 0.02 y

- [1]SGR=Specific Growth Rate
- [2]K=condition factor=[weight/(length^3)] × 10^5

At the end of the second period, final tank weight, and gain were significantly greater in tanks containing vertically-suspended environmental enrichment compared to the control tanks.

Mean feed conversion ratios were 1.19 and 1.11 in the control and enrichment groups, respectively, but were not significantly different. Mean individual fish lengths at the end of the second period were 164 and 175 mm and mean weights were 51 and 65 g in the control and enriched groups, respectively, but were also not significantly different. Condition factor was significantly higher in the fish reared with structure.

The overall feed conversion ratios, obtained by combining the results from both periods, were 1.15 in the unenriched control group and 1.07 in the enriched group.

Discussion

The increase in total tank weight gains with enrichment in the second period and overall is not surprising. Improvements in growth using vertically-suspended environmental enrichment in juvenile salmonids after the initial feeding phase have been widely reported [15,16,18-20,22,24,28]. The results for the first rearing period differ from those reported by Huysman et al. [25] who reported a significant improvement in growth and feed conversion ratio in Chinook salmon reared with vertically-suspended environmental enrichment shortly after initial feeding however. These differences could be because of the different species evaluated. Näslund and Johnsson [14] suggested that environmental enrichment may need to be modified for individual salmonid species or due to other genetic differences. In addition, the rainbow trout used in this study were a domesticated strain, where-as the Chinook salmon used by Huysman et al. [25] were obtained by spawning wild broodstock.

Changes in circular tank water velocity profiles due to the suspended structural array are likely the reason for the increase in trout growth. Significant decreases in water velocities behind vertically-suspended environmental enrichment have been reported by Moine, Barnes, et al. Muggli, Barnes, et al. Caasi, Barnes, et al. [29-31]. The microhabitats resulting in the lower velocity areas likely decrease fish energy expenditures, particularly while feeding [16,32]. In addition, the variety of water velocities would also provide rearing benefits due to exercise [16,24,33-35].

The lack of impact on circular tank hydraulic self-cleaning observed in this study is similar to that reported previously by Kientz, Barnes, Crank, Kientz, et al. White, Krebs et al. [16,19,22]. While other vertically-suspended structures can decrease circular tank velocity profiles below the self-cleaning threshold [30,31], production fish hatcheries can use the structure described in this study and not incur additional labor costs due to increased tank cleaning demands.

The lack of differences observed in the first rearing period may have been due to the short duration of only 48 days. The National Research Council [36] recommends that all diet-related fish studies should last at least 56-84 days. However, Huysman et al. [25] was able to detect significant differences between Chinook salmon reared initially with or without suspended structure after only 32 days. The small sample sizes may have also hindered the ability to detect significant differences [37]. Lastly, the results of this study may have been negatively affected by the relatively high rearing densities experienced at the end of the second period [38] suggested an upper limit for the rearing density of rainbow trout of 50 kg m^{-3} for each tank. The tank densities at the end of the second period in this experiment were 76.9 kg m^{-3} for the unenriched tanks and 83.8 kg m^{-3} for the enriched tanks [38].

Conclusion

The results of this study support the use of vertically suspended structure as environmental enrichment to improve the hatchery rearing performance of juvenile rainbow trout. However, it may not be needed during the period of initial feeding. Additional research using larger sample sizes and different fish species should be conducted on environmental enrichment during initial feeding or shortly there-after.

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