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Use of Two Vertically-Suspended Environmental Enrichment Arrays during Rainbow Trout Rearing in Circular Tanks

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Abstract: *Environmental enrichment is the inclusion of materials into hatchery tanks to create a more natural rearing environment. This study examined the use of both single and double arrays of vertically-suspended aluminum angles as environmental enrichment during the culture of rainbow trout (Oncorhynchus mykiss) in 1.8-m diameter circular rearing tanks. After 110 days of rearing, rainbow trout were significantly longer, heavier, and had a higher specific growth rate in tanks containing either one or two arrays compared to control tanks devoid of any structure. However, there were no significant differences between the two environmental enrichment treatments. Total tank weight gain and feed conversion ratio were not significantly different among the treatments. In comparison to the single array, the use of two arrays did not improve growth and also interfered with the hydraulic self-cleaning of the circular tanks.*

Keywords: *Oncorhynchus mykiss, environmental enrichment, structure, growth*

1. Introduction

Circular tanks are used for fish rearing because they homogeneously distribute oxygen, provide velocity for fish exercise, and are hydraulically self-cleaning [1-6]. However, they are typically barren, devoid of any internal structures usually found in complex natural environments. Environmental enrichment is the practice of placing structure within hatchery rearing units, or otherwise modifying them to more closely resemble natural habitats.

Environmental enrichment techniques vary in their complexity and forms, ranging from cobble based bottom structures [7, 8], tree branches and tops [9-11], plastic pipes and plants [12, 13], to vertically-suspended structures[14-19]. Compared to other forms of enrichment, vertically-suspended structures are advantageous because they do not interfere with circular tank hydraulic self-cleaning [14-19], thereby minimizing hatchery labor and the risk of disease [20, 21]. In addition, vertically-suspended structure has been shown to dramatically improve salmonid rearing performance [14-19].

Most of the prior experiments with vertically-suspended structure used relatively small arrays of aluminum rods, aluminum angles, plastic pipes, or a small number of equidistantly-spaced strings of colored balls [14-17]. Crank et al. [19] expanded the size of the vertically-suspended enrichment to include either a higher number of suspended strings or a combination of aluminum rods and strings. Positive results were noted during salmonid rearing using either approach [19]. However, the inclusion of more than one vertically-suspended array has never been evaluated. Thus, the objective of this study was to determine the effects of two arrays of vertically-suspended aluminum angles on rainbow trout (*Oncorhynchus mykiss*) performance during hatchery rearing.

2. 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 mgL^{-1}; alkalinity as $CaCO_3$, 210 mg L^{-1}; pH, 7.6; total dissolved solids, 390 mg L^{-1}). Approximately 2,400(8.4 kg tank) juvenile Shasta strain rainbow trout (mean ± SE weight =3.6±0.2 g; length = 69 ± 1.25 mm; n = 30), were placed into 12, 2,000-L circular tanks (1.8 m diameter, 0.8 m deep, 0.6 m operating depth) at an incoming water velocity of 12.2 cms^{-1} on May 31, 2018. This study lasted 110 days and ended on September 18, 2018.

In addition to control tanks with no structure, two different enrichment treatments were used. One treatment consisted of a single array of four aluminum angles (2.5 cm wide on each angle side x 57.15 cm long) suspended vertically through a corrugated plastic tank cover as described by Krebs et al. [16] (Figure 1). The other treatment suspended an additional and identical four-angle array (Figure 2).The angles were positioned so that the angle faced into the water flow. Four tanks were used for each treatment (*n* = 4).

Fish were fed 1.5 mm, extruded floating trout diet (Classic Trout, Skretting USA, Tooele, Utah, USA) every 15 min during daylight hours using automatic feeders. Feeding rates were initially determined by the hatchery constant method [22], with an expected feed conversion ratio of 1.1 and a projected growth rate of 0.08 cm d^{-1}, to attain a rate at or slightly above satiation. Feeding rates were adjusted based on consumption. At the end of the experiment total tank weights were obtained by weighing all fish in each tanks to the nearest 0.1 kg. Also, ten fish per tank were individually measured (total length) and weighed to the nearest 1.0 mm and 0.1 g. The following formulas were used:

$$\text{Percent gain (\%)} = 100 * \frac{\text{gain}}{\text{start weight}}$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{food fed}}{\text{gain}}$$

$$\text{Specific growth rate (SGR)} = 100 * \frac{\ln(\text{end weight}) - \ln(\text{start weight})}{\text{number of days}}$$

$$\text{Condition factor (K)} = 10^5 * \frac{\text{fish weight}}{\text{fish length}^3}$$

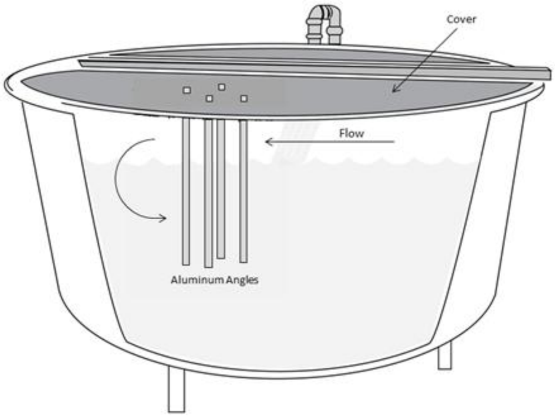

Figure 1. *Circular tank with a suspended single array of four aluminum angles, with the peak of the angle facing in the direction of the water flow*

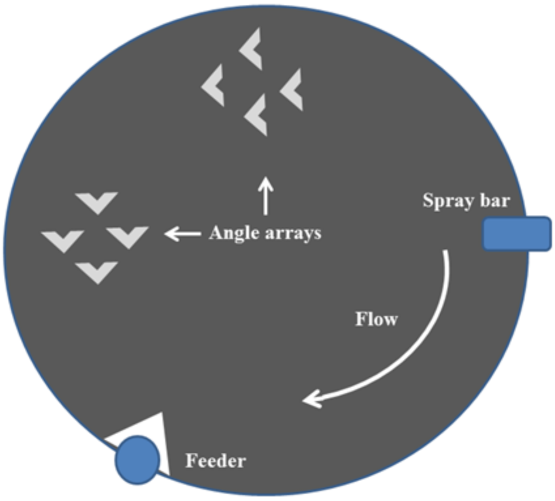

Figure 2. *View from the top of a covered circular tank with two angle arrays.*

Data was analyzed using the SPSS (9.0) statistical program (SPSS, Chicago, Illinois, USA), with significance predetermined at $P< 0.05$. Individual and total tank metrics were analyzed using a one-way analysis of variance. If treatments were determined to be significantly different a post hoc means separation test was performed using the Tukey HSD test.

3. Results

Fish in tanks enriched with either of the suspended angle treatments were significantly longer, heavier, and had significantly higher specific growth rates than fish from control tanks (Table 1). There were no significant differences in length, weight, or specific growth rate between the two angle treatments however. Mean percent gain ranged from 1,143% for the control tanks to 1,323% for the double-array tanks, but there was no significant difference among any of the treatments (Table 2). Feed conversion ratio was also not significantly different among the control or either angle treatment group.

Table1. *Mean (± SE) total length, weight, condition factor (K)[a], and specific growth rate (SGR)[b] for rainbow trout reared in circular tanks with either no environmental enrichment (control) or a single or double array of vertically-suspended angles (means followed by different letters are significantly different).*

	Control	Single array	Double array	F	P
Length (mm)	156 ± 2 z	165 ± 1 y	166 ± 2 y	13.72	0.00
Weight (g)	45.2 ± 2.9 z	55.9 ± 0.8 y	55.6 ± 2.5 y	7.26	0.01
K	1.19 ± 0.03	1.26 ± 0.01	1.21 ± 0.03	7.24	0.01
SGR	2.34 ± 0.06 z	2.54 ± 0.01 y	2.53 ± 0.04y	1.45	0.28

[a] *$K = 10^5$ x (weight / length^3)*

[b] *SGR = 100 x [(Ln end weight – Ln start weight) / number of days]*

Table2. *Mean (± SE) food fed, percent gain, and feed conversion ratio (FCR)[a] of rainbow trout reared in circular tanks with either no environmental enrichment (control) or a single or double array of vertically-suspended angles.*

	Control	Single array	Double array	F	P
Food fed (kg)	99.5 ± 0.8	99.5 ± 0.8	100.3 ± 0.0	0.50	0.62
Gain (%)	1,143 ± 72	1,249 ± 52	1,323 ± 55	2.25	0.16
FCR	1.05 ± 0.06	0.95 ± 0.03	0.91 ± 0.04	2.61	0.13

[a] *FCR = Food fed / Total weight gain*

4. Discussion

The significant improvement in fish length, weight, and specific growth rate with either of the vertically-suspended angle environmental enrichment treatments is not surprising. Numerous other studies have documented improved salmonid growth using other vertically-suspended enrichment techniques [14-19]. However, White et al. [23] reported no improvement in the growth of brown trout (*Salmo trutta*), Chinook salmon (*Oncorhynchus tshawytscha*), and Atlantic salmon (*S. salar*) reared in circular tanks with a relatively small array of vertically-suspended aluminum rods for relatively short time-frames. The lack of significant improvement in gain or feed conversion ratio in this study is surprising. However, the relatively low P values, approaching significance for both of these variables, indicates that additional replication may likely decrease the variances resulting in statistically-significant differences [24].

Vertically-suspended environmental enrichment dramatically changes circular tank flow dynamics [25, 26]. These changes likely lead to bio-energetic benefits by creating lower velocity microhabitats favorable to juvenile salmonids [27]. In addition, fish reared with angle arrays may be benefitting from periodic exercise [26]. Fish benefit from higher velocity-induced exercise during hatchery rearing [4, 28-30]. However, continual exercise for long periods of time can be detrimental to fish growth [5, 6]. By creating slower velocity areas within the tank, the suspended arrays may allow the fish the opportunity to rest after exposure to the higher velocity areas of the tank, thereby creating a natural exercise regime [31]. The trout reared with structure are also likely experiencing reduced stress, which may also be contributing to the increased growth observed [32].

The addition of a second angle array did not improve individual fish or total-tank metrics compared to the single array. Crank et al. [19] reported comparable results with the addition of more enriching material. They found similar improvements in salmonid growth with the use of either five or eight vertically-suspended strings of balls. In addition, using a combination of both an array of vertically-suspended rods and equidistantly-spaced strings of balls resulted in reduced growth compared to the eight vertically-suspended strings of balls. Thus, there appears to be upper limits on the amount of vertically-suspended structure that can be used to improve fish rearing performance. Simply addition extra structures to fish rearing tanks does not appear to positively affect the fish and can actually negatively affect the tank environment by eliminating or reducing circular tank hydraulic self-cleaning [19, 26, 33].

5. Conclusion

The results of this study support the use of vertically-suspended structures as a form of environmental enrichment to benefit rainbow trout hatchery rearing performance. However, these growth benefits do not increase with the inclusion of an additional suspended array, and the use of two arrays interfered with circular tank hydraulic self-cleaning. Thus, the use of a relatively small, single array is recommended during rainbow trout culture in circular tanks.

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