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**Eric Krebs, Nathan Huysman, Jill M Voorhees and Michael E Barnes***

South Dakota Department Game, Fish and Parks, McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, South Dakota, USA

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***Corresponding author:** Michael E Barnes, South Dakota Department Game, Fish and Parks, McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, South Dakota 57783, USA,
E-mail: mike.barnes@state.sd.us

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Research Article

# Suspended Arrays Improve Rainbow Trout Growth during Hatchery Rearing in Circular Tanks

## Abstract

Environmental enrichment can be an effective tool to improve rearing efficiencies during hatchery production. This study evaluated the effectiveness of two different vertically-suspended arrays in circular tanks on the growth of juvenile rainbow trout *Oncorhynchus mykiss.* Treatments consisted of an array of suspended aluminum rods, an array of suspended aluminum angles, or no suspended structures (control) in this 141 day study. Weight gain and feed conversion ratio were significantly improved in fish reared in tanks containing either of the suspended structures compared to unenriched control tanks. The use of either vertical rods or angles is recommended during rainbow trout rearing in circular tanks, although using angles may be more desirable because they require less material to construct.

## Introduction

Hatchery rearing units are typically barren environments. Enrichment of otherwise sterile rearing tanks occurs when structure is added [1]. Several studies have used different environmental enrichment techniques, frequently by adding woody debris, stones, or other various materials [2-8] with the goal of altering fish behavior, improving fish physiology, or increasing post-stocking survival [1,2,6,9]. However, placing structure into fish tanks can hinder routine fish culture activities, such as tank cleaning, as well as increase the risk of potential disease outbreaks by trapping food and feces [8,10,11]. However, Donnelly and Whoriskey [12], Kientz and Barnes [13], and Kientz et al. [14], describe environmental enrichment techniques that do not interfere with the self-cleaning rotational velocities inherent to circular tanks [15-17].

Both Kientz and Barnes [13] and Kientz et al. [14] describe the use of an array of suspended aluminum rods in circular tanks during salmonid rearing. These environmental enrichment structures improved rainbow trout (*Oncorhynchus mykiss*) growth and feed conversion. However, the number of rods used in each array constituted a significant linear amount of raw material. In addition, removal of the relatively large number of rods to observe the fish or remove mortalities was an awkward and cumbersome process. Lastly, the nuts suspending the rods were subject to loosening, requiring diligence on the part of hatchery staff to ensure the rods did not fall into the tanks. An alternative to the rod array that would provide the same benefits during hatchery rearing, but would require less material to construct, be less difficult to remove, and not require periodic inspections, was needed. Thus, the objective of this study was to examine the effects of a novel array of suspended structure comprised of suspended aluminum angles on the growth and feed conversion of rainbow trout.

## Materials and Methods

Experimentation occurred at McNenny State Fish Hatchery, rural Spearfish, South Dakota, USA using nine circular fiberglass tanks (1.8 m in diameter, 0.8 m deep, 0.6 m operating depth). Each tank received approximately 45 L/min of aerated and degassed well water (11° C; water hardness as $CaCO_3$ - 360 mg/L; alkalinity as $CaCO_3$ - 210 mg/L; pH - 7.6; total dissolved solids - 390 mg/L). The study began on November 28, 2017 and ended April 17, 2018, a total of 141 days. At the start of the experiment, each of nine tanks received 3.38 kg (approximately 1,800 fish) of juvenile Erwin-Arlee strain rainbow trout (mean weight and length of 1.8 g and 54 mm, respectively). All nine tanks were near fully-covered, with only a small opening for the automatic feeder [18,19].

Two environmental enrichment treatments were used, along with one unenriched control treatment (N=3). Three treatment tanks received a vertically-suspended array of four aluminum angles (each side 2.5 cm wide, 57.15 cm long; Figure 1) and three treatment tanks received a vertically-suspended array of nine round aluminum rods (0.95 cm diameter, 57.15 cm long; Figure 2). The angles were positioned with their peak faced into the direction of water flow in the tanks. The angles



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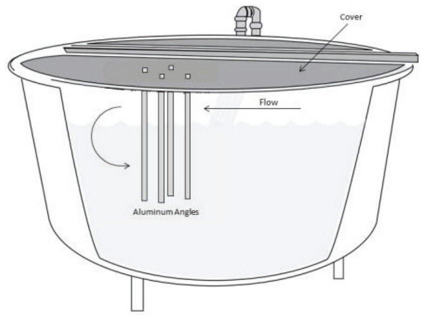


**Figure 1:** Circular tank with a suspended array of four aluminum angles, with the peak of the angle facing in the direction of the water flow.

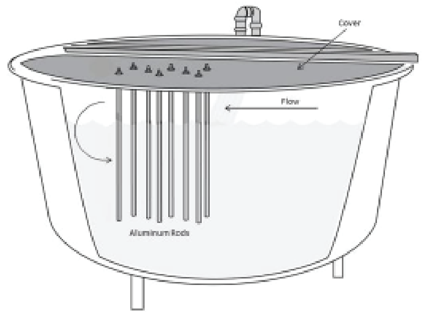


**Figure 2:** Circular tank with a suspended array of nine aluminum angles.

were constructed with an aluminum rectangular plate welded flat to one end to act as a stop. The angles were then inserted into the tank covers through holes cut to match their shape. The rods were constructed with one end partially threaded to accept a nut and washer, and inserted through holes in the tank cover as described in Kientz and Barnes [13] and Kientz et al. [14].

Fish were fed 1.5-mm extruded floating pellets (Pro-Tec, Skretting, Tooele, Utah, USA) based on a hatchery constant of 7.26 (0.065 mm/day) with an anticipated feed conversion ratio of 1.1 [20]. Feed were dispensed from EWOS 505 (Norco-last AS, Sweden) automatic feeders between 08:00 to 18:00 for 1 min at 20-min intervals. Feed rations, along with the number and weight (to the nearest 0.1 g) of mortalities, were recorded daily for each tank.

Total biomass (to the nearest 5 g) for each tank was measured at the beginning and end of the experiment using an Ohaus model T1XW scale (Parsippany, New Jersey, USA). At the end of the experiment, total lengths to the nearest 0.01 mm and weights to the nearest 0.1 g were recorded from five randomly-selected individual fish from each tank using a model ER-120A A&D electronic balance (Tokyo, Japan) and digital calipers. The following equations were used to calculate Condition Factor (K) and Feed Conversion Ratio (FCR):

$$K = [\text{weight (g)} / \text{total length (cm)}^3] \times 10^5$$

$$FCR = \text{feed fed (g)} / \text{weight gain (g)}$$

Data were analyzed using the SPSS (9.0) statistical analysis program (SPSS, Chicago, Illinois, USA). Individual tanks were the experimental units, not individual fish. Thus, for individual fish lengths and weights, the mean of the individual fish sampled in each tank was used for analysis. One-way analysis of variance (ANOVA) was conducted, and if the treatments were significantly different, pairwise mean comparisons were performed using the Tukey HSD test. Because of the small sample sizes used in this experiment (N=3), significance was predetermined at $P < 0.10$ [21].

## Results

Total tank gain and feed conversion ratios were significantly greater in tanks with arrays of aluminum angles or rods in comparison to control tanks with no structure (Table 1). Individual fish length, weight and condition factor was not significantly different among the treatments (Table 2). Percent mortality was also not significantly different among the treatment groups.

**Table 1:** Mean ± SE total weights, gain, food fed, feed conversion ratio (FCR*), and percent mortality from tanks of rainbow trout reared in unenriched circular tanks or tanks with an array of suspended aluminum angles or rods. Means in a row with different letters are significantly different (*N* = 3, *P* < 0.10).

| | Environmental Enrichment | | | |
|---|---|---|---|---|
| | Control | Rods | Angles | *P* |
| Start weight (kg) | 3.38 | 3.38 | 3.38 | |
| Food fed (kg) | 100.55 | 100.55 | 100.55 | |
| End weight (kg) | 100.67 ± 1.35 z | 107.13 ± 2.99 z | 108.40 ± 2.72 z | 0.136 |
| Gain (kg) | 97.53 ± 1.39 z | 103.94 ± 3.01 y | 106.29 ± 1.76 y | 0.068 |
| FCR* | 1.03 ± 0.01 z | 0.97 ± 0.03 y | 0.95 ± 0.01 y | 0.060 |
| Mortality (%) | 4.00 ± 1.73 z | 2.33 ± 0.88 z | 4.33 ± 2.03 z | 0.665 |

*FCR = Feed Conversion Ratio = Food fed / gain.

**Table 2:** Mean ± SE final individual fish lengths, weights, and condition factors (K*) of rainbow trout reared in unenriched circular tanks or tanks with an array of suspended aluminum angles or rods (*N* = 3).

| | Environmental Enrichment | | | |
|---|---|---|---|---|
| | Control | Rods | Angles | *P* |
| Length (mm) | 170 ± 1 | 173 ± 2 | 173 ± 3 | 0.497 |
| Weight (g) | 60.2 ± 3.3 | 61.8 ± 1.6 | 63.9 ± 5.2 | 0.778 |
| K* | 1.22 ± 0.07 | 1.18 ± 0.02 | 1.22 ± 0.08 | 0.879 |

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

## Discussion

The results of this study indicate that a much smaller array of four suspended angles provided the same benefits during juvenile rainbow trout rearing as a much larger array of nine suspended aluminum rods. The increase in total tank weight gain and FCR with the use of either vertically-suspended structure array is similar to that reported for suspended rod arrays by Kientz and Barnes [13] and Kientz et al. [14], as are the feed conversion ratios. The rainbow trout used in this study were only 1.8 g and 54 mm, which was much smaller than the 12.3 g and 104 mm rainbow trout used by Kientz and Barnes [13] and the 7.9 g and 90 mm rainbow trout used by Kientz et al. [14], potentially increasing the range of trout sizes positively affected by environmental enrichment.



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Kientz et al. [14], observed positive results using suspended rod arrays after only 70 days, whereas this study lasted 141 days. It is unknown if the suspended aluminum angle array produced any improvement in growth or feed conversion ratio sooner than 141 days. In an experiment with Atlantic salmon (*Salmo salar*), Brockmark et al. [5] reported no effects of environmental enrichment on growth after 123 rearing days, but did note positive effects after 311 days. It is possible that the effects and effect-timing of tank enrichment structures may be species specific [1].

With adequate incoming velocities, circular tanks are inherently self-cleaning [15-17]. Neither the suspended angle or rod arrays interfered with this self-cleaning nature. This was also reported for suspended rod arrays by Kientz and Barnes [13] and Kientz et al. [14]. Other environmental enrichment techniques, such as adding substrate to tank bottoms [1,8,9,22,23] or placing structure such as woody debris, plants, or roots into rearing units [2,3,5,6,24] impedes the self-cleaning dynamics of circular tanks. In addition, placing such structures into fish tanks can increase the risk of potential disease outbreaks by trapping food and feces [8,10,11], making them unsuitable for production fish hatcheries. In contrast, the suspended arrays of angles or rods do not increase labor demands and do not increase fish health risks.

The suspended angle and rod arrays may be positively affecting trout growth and feed conversion by altering the circular tank water velocity profiles [25]. The suspended structures may be creating lower velocity water pockets, which allow the trout to minimize their foraging energy expenditures [26]. At the same time, the fish are provided the benefits of exercise in higher-velocity portions of the tank [27].

## Conclusion

The use of suspended arrays of either aluminum angles or rods improves rainbow trout growth and feed conversion ratios compared to control, unenriched, tanks. Using either environmental enrichment technique is appropriate, but the use of angles is recommended because they require less material to construct, are less cumbersome to remove, and have no parts which may loosen over time.

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