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Review Article

A comparison of blue and silver vertically-suspended environmental enrichment during Chinook Salmon and Rainbow trout rearing

Michael J Robidoux, Thomas Mauck, Nathan Huysman, Jill M Voorhees* and Michael E Barnes

South Dakota Department of Game, Fish and Parks, USA

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***Corresponding author:** Jill M Voorhees, Fishery Biologist, South Dakota Department of Game, Fish and Parks, 19619 Trout Loop, Spearfish, SD, 57783, USA, Tel: 1-605-642-6920; Fax: 1-605-642-6921; E-mail: jill.voorhees@state.sd.us

ORCID: https://orcid.org/0000-0001-7993-1091

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Abstract

This study evaluated the use of either blue or silver vertically-suspended environmental enrichment in two experiments, with one rearing Chinook salmon (*Oncorhynchus tshawytscha*) for 29 days and the other rearing rainbow trout (*Oncorhynchus mykiss*) for 98 days. In both experiments, there were no significant differences in total tank weight, gain, percent gain, feed conversion ratio, or percent mortality between tanks with either silver (unpainted aluminum) or blue vertically-suspended environmental enrichment. Individual fish total length, weight, specific growth rate, and condition factor were also not significantly different between the two colors for both fish species. These results indicate that either silver (unpainted aluminum) or blue vertically-suspended environmental enrichment can be used during the hatchery rearing of juvenile Chinook salmon or rainbow trout.

Introduction

Color can affect fish growth, physiology, aggression, and stress response [1-9]. Color preferences can vary between fish species and can change in the same fish over time [10]. For example, black had a positive impact on the growth of African catfish (*Heterobrachus bidorsalis*) but had no effect on river catfish (*Pangasius hypophthalmus*) [11,12]. Red light increases growth in rainbow trout (*Oncorhynchus mykiss*) but decreases growth in gilthead seabream (*Sparus aurata*) [13,14]. Blue light increases stress in rainbow trout but decreases it in Nile tilapia (*Oreochromis niloticus*) [1,13]. Color can interact with other components of the rearing environment to impact fish. For example, red-brown substrate had a positive impact on gilthead seabream physiology when compared to green or no substrate [15-17].

Substrate adds to the structural complexity of otherwise barren hatchery tanks. Substrate and other forms of environmental enrichment generally have positive effects during hatchery rearing [18-23]. Kientz and Barnes [22], first demonstrated that vertically-suspended environmental enrichment can positively improve growth while maintaining the hydraulic self-cleaning of the circular tanks. Most of the studies evaluating vertically-suspended environmental enrichment have used unpainted structures such as aluminum angles, aluminum rods, or grey polyvinyl chloride electrical conduit [22-27]. Kientz, et al. [28] and Crank, et al. [29], used strings of randomly colored spheres which dramatically improved weight gain and feed conversion ratio in rainbow trout compared to those in barren tanks.

Only three studies have evaluated the color of vertically-suspended environmental enrichment. Jones, et al. [30], reported improved fish rearing production for juvenile Chinook salmon (*Oncorhynchus tshawytscha*) using green vertically-suspended angles. In contrast, Chapman, et al. [31], found no effect of using blue vertically-suspended angles for juvenile rainbow trout. And Meza, et al. [32], found no difference in rainbow trout rearing performance using either silver, red,

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black, green, or blue environmental enrichment. The objective of this study was to evaluate the use of blue and silver (unpainted) aluminum vertically-suspended environmental enrichment during the hatchery rearing of juvenile Chinook salmon and rainbow trout.

Methods

Methods common to both experiments

This study was conducted at McNenny State Fish Hatchery, rural Spearfish, South Dakota, the USA using degassed and aerated 11 °C well-water (water hardness as $CaCO_3$ = 360 mg/L, alkalinity a $CaCO_3$ = 210 mg/L, pH = 7.6, total dissolved solids = 390 mg/L). Each of the two experiments used 10, indoor, circular tanks (diameter = 1.8 m, height = 0.8 m, water depth = 0.6 m). All tanks were nearly fully covered [33], with four aluminum angles (2.5 cm wide × 57.15 cm long) suspended through the covers as described by Krebs, et al. [23], (Figure 1). Feeding rates used the hatchery constant method [34], with an expected feed conversion ratio of 1.1 and a projected growth rate of 0.075 cm/day. All fish were fed every 20 minutes during daylight hours using automatic feeders and were fed at rates that are at, or slightly above, satiation. Dead fish were removed daily. Both studies started on 10 February 2021.

There were two treatments in each experiment, with vertically-suspended environmental enrichment (aluminum angles) either silver (unpainted) or blue. The blue aluminum angles were painted with OSHA standard safety-blue paint (Krylon, Krylon products Group, Cleveland, Ohio, USA).

Experiment 1: Chinook salmon

Chinook salmon (mean ± SE; total length: 55 ± 1 mm, weight: 1.4 ± 0.1 g, n = 50) from a common pool were placed into 10 tanks. Five tanks had silver (unpainted) angles and five had blue angles (n = 5). Each tank contained approximately 9,000 fish (initial tank weight: 15.4 kg). Fish were fed a commercial diet (BioVita Starter, Bio-Oregon, Longview, Washington, USA). This experiment lasted 29 days, ending on 10 March 2021.

Experiment 2: Rainbow trout

Rainbow trout (mean ± SE; total length: 52 ± 1 mm, weight: 1.5 ± 0.0 g, n = 50). from a common pool were placed into the 10 tanks. Five tanks had silver (unpainted) angles and five had blue angles (n = 5). Each tank contained approximately 3,200 fish (initial tank weight: 6.1 kg). Fish were fed a commercial diet (Protec, Skretting, Toole, Utah, USA). This experiment lasted 98 days, ending on 19 May 2021.

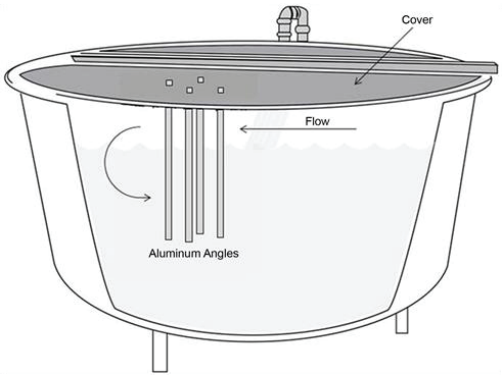

Figure 1: Circular tank with a suspended array of four aluminum angles, with the peak of the angle facing in the direction of the water flow.

Statistical analysis

At the end of the experiment, total lengths to the nearest mm and weights to the nearest 0.1 g were recorded for ten fish from each tank. Condition factor (K) and specific growth rates (SGR) were calculated using the following formulas:

$$K = 10^5 \times \frac{fish\ weight}{fish\ length^3}$$

$$SGR = 100 \times \frac{\ln(end\ weight) - \ln(start\ weight)}{number\ of\ days}$$

Total tank weight was obtained by weighing all the fish in a tank. Gain, percent gain, feed conversion ratio (FCR), and percent mortality were calculated using the following formulas:

$$Gain = end\ weight - start\ weight$$

$$Gain\ (\%) = 100 \times \frac{gain}{start\ weight}$$

$$FCR = \frac{food\ fed}{gain}$$

$$Mortality\ (\%) = 100 \times \frac{number\ of\ dead\ fish}{initial\ number\ of fish}$$

The SPSS (24.0, IBM, Armonk, New York, USA) statistical program was used for data analysis. One-way analysis of variance was performed with significance pre-determined at $p < 0.05$.

Results

Experiment 1: Chinook Salmon

Final mean tank weight, gain, percent gain, feed conversion ratio, and percent mortality was not significantly different between the tanks of salmon reared with either silver or blue vertically-suspended environmental enrichment (Table 1; p - value: 0.321, 0.321, 0.321, 0.320, and 0.383, respectively). For example, the final mean (± SE) percent gain was 132 (± 15) for fish reared in the tank with silver (unpainted) aluminum angles and 149 (± 5) for fish reared with blue aluminum angles. Final individual mean fish total length, weight, condition factor, and specific growth rate were also not significantly different between salmon reared with either silver or blue vertically-suspended environmental enrichment (Table 2; p - value: 1.000, 0.572, 0.136, and 0.075, respectively). For example, the final individual mean (± SE) weight was 3.7 (± 0.2) g for the fish reared with silver angles compared to 3.9 (± 0.2) g for fish reared with blue angles.

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Experiment 2: Rainbow Trout

Final mean tank weight, gain, percent gain, feed conversion ratio, and percent mortality was not significantly different between the tanks of rainbow trout reared with either silver or blue vertically-suspended environmental enrichment (Table 1; p - value: 0.258, 0.258, 0.258, 0.265, and 0.130, respectively). For example, the final mean (± SE) feed conversion ratio was 0.8 (± 0.00) for fish reared in the tank with silver (unpainted) aluminum angles and 0.8 (± 0.00) for fish reared with blue aluminum angles. Final individual fish total length, weight, condition factor, and specific growth rate were also not significantly different between salmon reared with either silver or blue vertically-suspended environmental enrichment (Table 2; p - value: 0.279, 0.296, 0.332, and 0.924, respectively). For example, the final individual mean (± SE) specific growth rate was 3.0 (± 0.1) for the fish reared with silver angles compared to 2.9 (± 0.1) g for fish reared with blue angles.

Table 1: Final mean (± SE) tank weight, gain, percent gain, feed conversion ratio (FCR)[1], and percent mortality for Chinook salmon (reared for 29 days) and rainbow trout (reared for 98 days) reared with silver or blue angles ($p < 0.05$; $n = 5$).

Variable	Silver angles	Blue angles	P - value
Chinook Salmon			
Final tank weight (kg)	35.8 ± 2.2	38.3 ± 0.8	0.321
Gain (kg)	20.4 ± 2.2	22.9 ± 0.8	0.321
Gain (%)	132 ± 15	149 ± 5	0.321
FCR	1.06 ± 0.20	0.90 ± 0.03	0.320
Mortality (%)	1.6 ± 0.4	2.0 ± 0.3	0.383
Rainbow Trout			
Final tank weight (kg)	99.3 ± 1.3	101.8 ± 1.6	0.258
Gain (kg)	93.2 ± 1.3	95.7 ± 1.6	0.258
Gain (%)	1,533 ± 22	1,574 ± 26	0.258
FCR	0.80 ± 0.00	0.80 ± 0.00	0.265
Mortality (%)	0.1 ± 0.0	0.2 ± 0.0	0.130

[1] FCR = (food fed) / (gain)

Table 2: Final individual mean (± SE) total length, weight, specific growth rate (SGR)[1], and condition factor (K)[2] of Chinook salmon (reared for 29 days) and rainbow trout (reared for 98 days) reared with silver or blue angles ($p < 0.05$; $n = 5$).

Variable	Silver angles	Blue angles	*P* - value
Chinook Salmon			
Length (mm)	73 ± 1	73 ± 1	1.000
Weight (g)	3.7 ± 0.2	3.9 ± 0.2	0.572
SGR	3.6 ± 0.2	4.0 ± 0.2	0.136
K	0.9 ± 0.1	1.0 ± 0.0	0.075
Rainbow Trout			
Length (mm)	135 ± 3	131 ± 3	0.279
Weight (g)	27.6 ± 2	25.0 ± 1.3	0.296
SGR	3.0 ± 0.1	2.9 ± 0.1	0.332
K	1.1 ± 0.0	1.11 ± 0.0	0.924

[1] SGR = 100 × [(ln(end weight) - ln(start weight)) / number of days]
[2] $K = 10^5 \times$ [(fish weight) / (fish length)^3]

Discussion

The results of the experiment using Chinook salmon add to the observations of Jones, et al. [30] who noted an improvement in salmon growth using green vertically-suspended environmental enrichment in comparison to silver, red, and black structures. The present study found no effects with blue vertically-suspended environmental enrichment. It was hypothesized that blue would be beneficial, given the predominance of blue visual pigment cones in juvenile Chinook salmon eyes [35]. This obviously did not occur within the relatively short 29-day duration of this study.

The results of this study, whereby rainbow trout growth was unaffected by either of the two colors of vertically-suspended environmental enrichment, are similar to those reported by Chapman, et al. [31] and Meza, et al. [32] who also examined rainbow trout. The Chapman, et al. [31], study was relatively short and found no difference in rainbow trout growth using red, green, and blue vertically-suspended environmental enrichment. Meza, et al. [32] used rainbow trout with initial lengths of 78 mm and observed no difference in growth after 86 days of rearing with either silver, red, black, green, or blue vertically-suspended environmental enrichment. The rainbow trout used in this study was much shorter at 52 mm, was reared for a longer duration of 98 days, and produced similar results comparing just two colors, silver, and blue.

The impact of color during rainbow trout rearing is uncertain. Luchiari and Pirhonen [36], observed that green environments increased trout growth compared to blue, red, white, or yellow environments. In contrast, Karakatsouli, et al. [14] reported that red light increased rainbow trout growth, and Üstündağ and Rad [37], observed better growth in beige tanks relative to green or gray tanks. Lastly, black tanks reduced rainbow trout growth [38]. Thus, while rainbow trout are likely influenced by color in the rearing environment, such influences may be impacted by the amount of color, light intensity, duration of exposure, life stage, genetics, or temperature [10,36,39].

The results of this study may have been impacted by the relatively small colored surface area of the vertically-suspended aluminum angles. In comparison to the color of the entire tank, the small amount of color in the suspended structure may not be enough to have any effect on fish growth [31,32]. Other potential factors influencing the results include tank covers [33], the 11°C water temperature [36], and the size of the fish [38]. Genetics also likely plays a part in color preferences as indicated by the differences among salmonid species [7,13,14,30-32,36-38].

In conclusion, the results of this study indicate that either silver (unpainted aluminum) or blue vertically-suspended environmental enrichment are acceptable for use during the hatchery rearing of juvenile Chinook salmon and rainbow trout. Additional research is needed on different colors and different life stages.

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