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Color of Vertically-Suspended Structure Does Not Impact the Growth of Rainbow Trout Reared in Circular Tanks

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Abstract

This study examined the effects of five different colors of vertically-suspended environmental enrichment on the growth of juvenile Shasta strain rainbow trout (*Oncorhynchus mykiss*) during hatchery rearing in circular tanks. The colors used were silver (unpainted aluminum—control), safety red, semi-gloss black, hunter green, and safety blue. After 86 days, total tank weight, weight gain, and feed conversion ration were not significantly different among any of the color treatments. Individual fish weights, lengths, and condition factors were also not significantly different among the treatments. The results of this study indicate that the relatively small amount of color present on the suspended structure did not affect rainbow trout growth. Thus, the inherent silver color of the aluminum angles does not need to be changed.

Keywords

Environmental Enrichment, *Oncorhynchus mykiss*, Salmonids, Color

1. Introduction

Color can impact fish reared in an artificial setting. The colors used during hatchery rearing likely affect growth, stress response, aggression, and body coloration [1]-[6]. However, these results are not uniform, indicating specific colors affect species differently. Blue has been shown to negatively affect the growth of rainbow trout (*Oncorhynchus mykiss*), but positively affect the growth of gilthead seabream (*Sparus aurata*) [7]. Pale colored tanks (white or beige) have led to increased weight gain in goldfish (*Carassius auratus*) [4] and rainbow trout [8], but negatively impacted weight gain in African catfish (*Heterobrachuys bidorsalis*) [9].

Hatchery rearing performance can also be influenced by the addition of real or synthetic materials into barren hatchery tanks as a form of environmental enrichment [10] [11] [12] [13]. The possible interaction between such structures and color has only been lightly studied. In a study comparing blue substrate, a photo of blue substrate, and a control, Batzina and Karakatsouli [14] observed that combination of both color and actual substrate produced the only positive effects. Jones *et al.* [15] reported an increase in landlocked juvenile Chinook salmon (*Oncorhynchus tshawytscha*) growth when reared with vertically-suspended arrays of aluminum angles painted green compared to arrays painted silver, red, or black. In contrast, Chapman *et al.* [16] reported no effects of different colored vertically-suspended arrays during the rearing of rainbow trout.

The Chapman *et al.* [16] and Jones *et al.* [15] studies were of very short duration, lasting only 54 days and 25 days, respectively. Neither of these studies lasted as long as the minimum study duration of 56 to 84 days recommended by the National Research Council [17] for fish feeding trials. Thus, the objective of this study was to evaluate the use of different colored vertically-suspended arrays during the longer-term rearing of rainbow trout.

2. Methods

This 86-day experiment was conducted at McNenny State Fish Hatchery, rural Spearfish, South Dakota, USA, using single-pass, degassed and aerated well water at a constant temperature of 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). On June 24, 2019, 20 circular tanks (diameter = 1.8 m, height = 0.8 m, water depth = 0.6 m) each received 23.1 kg of Shasta strain rainbow trout (approximately 3,500 fish). Individual trout mean ± SE total lengths and weights were 78 ± 2 mm and 5.1 ± 0.4 g (n = 30), respectively. Each tank was nearly fully covered with black corrugated plastic [18]. An array of four aluminum angles (each side 2.5 cm wide, 57.15 cm long) were suspended from the overhead covers as described by Krebs *et al.* [19].

The four angles of the array were all the same color in each tank. The colors of the angles were silver (unpainted aluminum, which acted as a control), safety red, semi-gloss black, hunter green, or safety blue. Treatments were randomly assigned with each colored array replicated in four tanks (20 total tanks with four tanks per color). The red and blue arrays were created by uniformly painting the angles with OSHA standard colored spray paint (Krylon, Krylon Products Group, Cleveland, Ohio, USA). The black and green arrays were created by spray painting the angles with gloss enamel (Rust-oleum, Rust-oleum Corporation, Illinois, USA). A MiniScan XE Plus spectrophotometer (HunterLab, Reston, Virginia, USA) was used to obtain digital color values for the colors of the tank and structures (**Table 1**).

All fish were fed 1.5-mm extruded floating feed (Protec, Skretting, Toole, Utah, USA) daily over an 8-hour period in 20-minute intervals using automatic

Table 1. Color value measurements taken with the MiniScan XE Plus. The top row is the color of the tanks, and the following are colors of the aluminum angles used in the array.

Color	*L*	*a**	*b**
Blue-green	50.41	−46.19	1.35
Silver	71.48	−1.92	2.01
Red	31.89	49.84	26.27
Black	9.14	−0.99	1.18
Green	26.54	−23.39	12.57
Blue	33.29	−7.22	−37.26

feeders. The hatchery constant method [20] was used to determine feeding rates at or slightly above satiation, with a projected growth rate of 0.08 cm/day.

Total tank weights were recorded to the nearest 0.2 kg using an Intercomp CS200 hanging scale (Medina, Minnesota, USA) at the end of the experiment. Also, at the end of the study, five randomly sampled fish from each tank were weighed to the nearest 0.1 g and total length measured to the nearest 1.0 mm. The following equations were used:

$$\text{Gain} = \text{final tank weight} - \text{initial tank weight.}$$

$$\text{Feed conversion ratio (FCR)} = \text{feed fed/gain.}$$

$$\text{Condition factor } (K) = 10^5 \times [\text{weight}/(\text{body length})^3].$$

One-way Analysis of Variance (ANOVA) was used to analyze the data with the SPSS (24.0) statistical analysis program (IBM, Armonk, New York, USA). Because the tanks were the experimental units, not individual fish, nested ANOVA was conducted on the individual fish data. Significance was pre-determined at $p < 0.05$.

3. Results

Total tank ending weight, gain, and feed conversion ratio were not significantly different among any of the color treatments (**Table 2**). Individual fish weights, lengths, and condition factors were also not significantly different among the treatments (**Table 3**).

4. Discussion

The results from this study support those of Chapman *et al.* [16], who concluded that the color of vertically-suspended environmental enrichment had no impact on juvenile rainbow trout growth during hatchery rearing. However, these results differ from Luchiari and Pirhonen [21] who reported increased rainbow trout growth in green environments, compared to blue, red, white, or yellow. Contrarily, Karakatsouli *et al.* [7] [22] observed increased rainbow trout growth using red light, while Papoutsoglou *et al.* [23] noted reduced rainbow trout growth in black tanks. Lastly, Üstündağ and Rad [8] reported increased rainbow

Table 2. Mean ± SE tank total weights, gain, food fed, and feed conversion ratios (FCR[a]) for rainbow trout reared with different colored enrichment structures ($n = 4$).

Color	Silver	Red	Black	Green	Blue	p-value
Final weight (kg)	121.0 ± 1.5	115.1 ± 4.2	120.0 ± 3.8	121.0 ± 2.0	127.1 ± 2.7	0.182
Gain (kg)	99.1 ± 2.5	93.9 ± 3.8	98.2 ± 3.9	100.2 ± 2.1	104.7 ± 2.9	0.235
Food fed (kg)	127	127	127	127	127	
FCR	1.30 ± 0.03	1.38 ± 0.05	1.32 ± 0.05	1.29 ± 0.03	1.23 ± 0.04	0.220
Mortality (%)	1.03 ± 0.40	1.87 ± 0.56	1.42 ± 0.56	2.00 ± 0.27	0.54 ± 0.19	0.141

[a]FCR = food fed/gain.

Table 3. Mean ± SE fish individual total lengths, weights, and condition factors (K^a) for rainbow trout reared with different colored enrichment structures ($n = 4$).

Color	Silver	Red	Black	Green	Blue	p-value
Length (mm)	146 ± 5	146 ± 5	150 ± 3	146 ± 3	146 ± 2	0.895
Weight (g)	36.1 ± 4.2	34.2 ± 3.5	36.7 ± 2.5	36.0 ± 2.5	37.5 ± 2.2	0.956
K	1.15 ± 0.03	1.08 ± 0.04	1.08 ± 0.01	1.16 ± 0.03	1.19 ± 0.03	0.056

[a]$K = 10^5 \times$ individual weight/body length^3.

trout growth in beige tanks compared to green or gray-colored tanks. These inconsistent and apparently contradictory results may be due to several reasons, including the amount of color present in the rearing unit, light intensity, water temperature, study duration, and the sizes and strains of rainbow trout used.

The relatively small surface area of the vertically-suspended structure used in this study in relation to the much larger tank surfaces may not have provided enough color to elicit a response from the trout [16]. In addition, the tanks in this study were covered, which eliminated most of the ambient light. Although this has been shown to positively impact trout growth [18], the interaction of such a low light intensity and small area of color may have impacted the ability of the trout retina to detect color differences [23].

At 86 days, this study exceeded the recommended duration for fish feeding trials by the National Research Council [17]. It was also 32 days longer than the Chapman *et al.* [16] study which also reported no significant effect of suspended structure color on rainbow trout growth during hatchery rearing. It is possible that this study lasted too long in relation to fish rearing densities. Voorhees *et al.* [24] and Huysman *et al.* [25] suggested that high rearing densities, such as those observed at the end of this study, may lead to density-dependent reduced growth rates. By allowing fish in the slower-growing treatments the time to catch up in size to those fish in faster-growing treatments that reach higher densities more quickly, longer study durations may preclude the determination of significant differences among treatments. However, because both this study and the much shorter Chapman *et al.* [16] experiment both were unable to detect any structural color impacts, it is unlikely that the results were impacted by rearing density.

The rainbow trout in this study were reared in a constant 11˚C water temperature, which may have influenced the results. Rainbow trout color preferences may be temperature dependent. Luchiari and Pirhonen [21] reported a color preference shift in rainbow trout from green at 12˚C to blue at 1˚C. Differences in temperature may also explain some of the previously noted differences among prior studies such as Papoutsoglou *et al.* [23], Karakatsouli *et al.* [7] [22], Luchiari and Pirhonen [21], and Üstündağ and Rad [8].

The results of this study are likely unique to the size and genetic strain of rainbow trout used. Salmonid color preferences may change with developmental stage over time [26] [27]. In addition, given the differences in color preferences among salmonids [5] [7] [8] [15] [21] [22] [23], and among different fish species [1] [2] [3] [4] [6] [9] [14] [28] [29] [30], it is possible that different rainbow trout strains would react differently to different colors.

Lastly, the source of color may have influenced the results of this study. Numerous other color investigations during fish rearing have focused on the color of the entire tank [2] [4] [6] [23] [31], rather than on structure within an already-colored tank. Lighting has also been used as a source of color, with fish held in tanks that match the color of the light source or tanks that are opaque or colorless [7] [22] [32] [33].

5. Conclusion

In conclusion, the results of this study indicate that the color of vertically-suspended environmental enrichment structures likely has little impact on rainbow trout growth in covered circular tanks. Thus, the inherent silver (unpainted aluminum) color of such structures does not need to be changed to produce additional rainbow trout rearing benefits beyond those of just using the structures themselves [19] [34] [35] [36] [37] [38]. Additional research investigating the effects of environmental enrichment colors should be conducted with other fish species and sizes.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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