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Predator Avoidance of Rainbow Trout Reared with Environmental Enrichment

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Abstract

Environmental enrichment involves the modification of hatchery rearing units to simulate a more natural environment. This study evaluated the effects of vertically-suspended structures during hatchery rearing on the survival of rainbow trout (*Oncorhynchus mykiss*) after placement in predator-rich, simulated post-stocking scenarios. Juvenile trout were reared in 1.8 m diameter circular tanks containing either a low density of suspended strings of balls, a high density of ball strings, a mixture of ball strings and aluminum rods, or no vertically-suspended structure (control). After 127 days, fifteen fish (mean ± SE; weight 74.4 ± 5.1 g; length 183 ± 3 mm) from each group were tagged and stocked, five fish per treatment, into three 30 m long raceways, each of which contained 15 adult brown trout (*Salmo trutta*) and arrays of concrete blocks for hiding cover. After four weeks, only three rainbow trout were eaten (one fish reared previously with low density strings of balls and two fish reared previously without any structure), and all of the remaining fish (both the juvenile rainbow trout and adult brown trout) were moved into a natural pond. Rainbow trout survival after four weeks in the pond was over 80% for all of the treatments and was not significantly different among the groups. This experiment failed primarily because of the overall lack of predation in the raceways and the lack of replication with the use of only one pond. However, the lessons learned from this unsuccessful experiment can be used to better design future post-stocking simulation studies for hatchery-reared trout.

Keywords: *Oncorhynchus mykiss;* Structure; Predation, Environmental Enrichment

Introduction

The main objective of conservation aquaculture is post-stocking survival, making it important for hatchery fish to look and behave similar to wild fish [1-5]. Environmental enrichment increases the complexity of the hatchery rearing unit to try and reduce the possible maladaptive traits of fish reared in typically sterile hatchery tanks [5]. Many studies have examined structural complexity as a form of environmental enrichment. Some of the structures placed into tanks to increase complexity include roots [5], tree tops or logs [5-9], cobble bottom (or any type of bottom sedimentary substrate) [5,9-14], imitative aquatic plants [4,5,15-20], and concrete blocks [21]. Yet, these structures are problematic for use in production hatcheries, particularly when used in circular tanks, because they interfere with hydraulic self-cleaning, requiring additional time for tank cleaning, and also creating conditions conducive to disease outbreaks [21-23].

Recently, Kientz and Barnes [24] described an environmental-enrichment technique suitable for large-scale production hatcheries. They used vertically-suspended arrays of aluminum rods which maintained tank hydraulic self-cleaning. Subsequent investigations involving a multitude of vertically-suspended structures have shown positive results on the hatchery rearing performance of a number of salmonids [25-29]. However, the impact of vertically-suspended environmental enrichment on post-stocking survival has not been evaluated.

Environmental enrichment has been shown to decrease the stress response in salmonids [18,30,31], which may in turn impact post-stocking survival. The addition of structure to hatchery rearing tanks may also impact predator avoidance [7,20]. The objective of this study was to evaluate the use of vertically-suspended environmental enrichment on post-stocking survival of hatchery-reared rainbow trout (*Oncorhynchus mykiss*), using simulated natural habitats with abundant predators.

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Methods

Raceways

Juvenile Erwin x Arlee strain rainbow trout were reared in circular tanks (1.8 m diameter × 0.8 m deep) that were almost fully covered [32] at McNenny State Fish Hatchery, in rural Spearfish, South Dakota, USA, using 11°C well water (total hardness as $CaCO_3$, 360 mg/L; alkalinity as $CaCO_3$, 210 mg/L; pH, 7.6; total dissolved solids, 390 mg/L). On January, 13, 2017 approximately 17,000 juvenile rainbow trout (initial weight 6.0 ± 0.3 g [mean ± SE], length 7.9 ± 0.6 cm, n=25) were combined into a common pool, and split evenly into twelve, 2,000 L, tanks. Each tank initially received 8.41 kg of fish (approximately 1,400 fish per tank). The 12 tanks were divided into four treatments: low density pit balls (Figure 1), high density pit balls (Figure 2), a mixture of low density pit balls and rods (Figure 3), and control (no structure) as described by Crank, et al. [29].

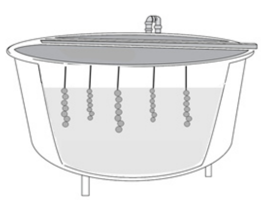

Figure 1: Schematic of Low Density Vertically-Suspended Ball Added to Tanks as Environmental Enrichment.

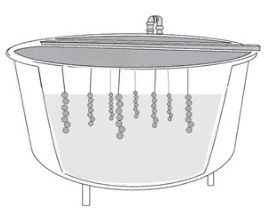

Figure 2: Schematic of High Density Vertically-Suspended Pit Ball Added to Tanks as Environmental Enrichment.

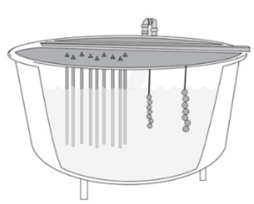

Figure 3: Schematic of A Mixture of Low Density Vertically-Suspended Ball Strings and Aluminum Rods Added to Tanks as Environmental Enrichment.

On May 23, 2017, after 127 days of rearing, five trout from each tank were weighed to the nearest gram, measured (total length) to the nearest mm (Table 1), and tagged with both visible implant (VI) tags (VI Alpha Tags, 1.2 mm x 2.7 mm, Northwest Marine Technology [NMT], Shaw Island, Washington, USA) and Coded Wire Tags (CWT) (1.1 mm, NMT, Shaw Island, Washington, USA) before being moved to one of three covered raceways (30 m x 2.4 m, depth = 0.76 m, operating depth = 0.3 m). Each raceway received five rainbow trout per treatment (20 rainbow trout total). Three arrays of commercially-available concrete blocks (Figure 4) were placed into each raceway, with the arrays located 6 m apart (Figure 5).

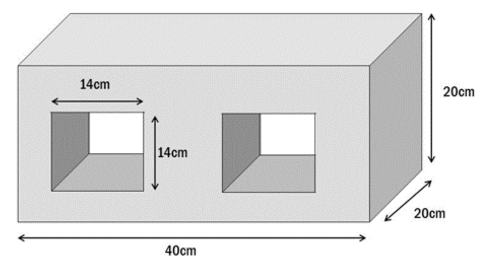

Figure 4: Schematic of Commercially Available Cement Cinder Block Used for Structure in The Raceways.

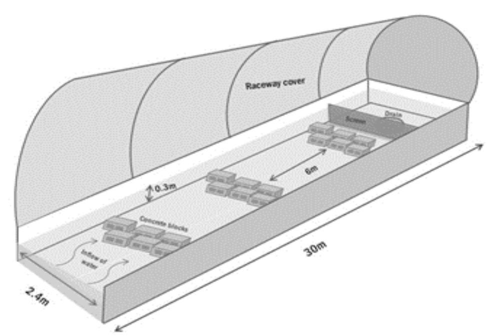

Figure 5: Schematic of Raceway with Structure Placement. The Left of the Picture Is the Upper End of the Raceway.

Treatment	Control	Mixture of Low Density Spheres and Rods	High density spherical structures	Low density spherical structures
Total length (mm)	170 ± 4z	187 ± 4y	189 ± 4y	188 ± 3y
Weight (g)	58 ± 4z	78 ± 6yz	81 ± 5y	80 ± 4y

Table 1: Mean (±SE) individual fish lengths and weights of rainbow trout raised in tanks containing different environmental enrichment. Means with different letters in the same row differ significantly ($P < 0.05$, n = 15).

To simulate a natural post-stocking scenario with predatory fish, 15 hatchery-reared adult brown trout (*Salmo trutta*) were also stocked into each of the three raceways (Table 2). No artificial feed was provided during the four weeks of the experiment; the smaller rainbow trout were the only food source for the brown trout. After four weeks, all of the fish were removed from each raceway, and tag information recorded for each of the rainbow trout. Any rainbow trout that were missing were assumed to be eaten by the brown trout.

Raceway	Total length (mm)	Weight (g)
1	381 ± 10	627 ± 43
2	364 ± 5	550 ± 24
3	365 ± 5	568 ± 25

Table 2: Mean (±SE) individual fish lengths and weights of brown trout (predators) stocked into raceways. There are no significant differences ($P < 0.05$, $n = 15$).

Mortality was analyzed using the SPSS (9.0) statistical analysis program (SPSS, Chicago, Illinois, USA). A univariate analysis test was performed with Tukey's post hoc multiple comparison test conducted if data was significant. Significance was pre-determined at $P < 0.05$.

Pond

Because of the minimal predation observed in the raceway, all 101 remaining raceway fish (both brown and rainbow trout) were moved to an uncovered pond. In addition to the brown trout, other potential predators included mink (*Neovison vison*), ospreys (*Pandion haliaetus*), belted kingfishers (*Megaceryle alcyon*), blue herons (*Ardea herodias*), and raccoons (*Procyon lotor*). The pond contained abundant vegetation for the fish to use as cover. After four weeks, the pond was drained, fish removed, and tag information recorded. Due to lack of replication, no statistics were performed on this data.

Results

Only a total of three rainbow trout were consumed by brown trout in all three of the raceways, with only one fish from the low density ball treatment and two fish from the control treatment presumably eaten (Table 3). No significant differences in mortality were observed between the treatments. The percentage of fish recovered from the pond from each of the treatments was similar (Table 4).

Raceway	Low density spherical structures	High density spherical structures	Mixture of low density spheres and rods	Control
1	1	0	0	0
2	0	0	0	2
3	0	0	0	0

Table 3: Number of mortality by treatment and raceway. There were no significant differences ($P < 0.05$).

Treatment	Percent survival
Low density spherical structure	85.7%
High density spherical structure	86.7%
Mixture of low density spheres and rods	80.0%
Control	84.6%

Table 4: Percent of Fish Recovered from Pond by Treatment.

Discussion

The lack of brown trout predation in the raceways in this study was problematic, and was likely due to a number of compounding reasons. The use of a relatively-domesticated brown trout strain may have played a part. Captively-bred salmonids exhibit a poorer transition to natural feed than wild fish [33], and wild brown trout in particular have been shown to be more effective predators than hatchery-reared brown trout [34]. It would have also been beneficial to train the brown trout on live feed prior to the start of the experiment [1,17,35,36]. Ward, et al. [34] found that feed trained hatchery-reared brown trout with minnows for 14-days increased their predation success. Lastly, predation may have been impacted by the size of the fish used in this study. Salmonids in general, and brown trout in particular, become piscivorous at or slightly above 30 cm [37,38]. At 37 cm, the brown trout used in this study were obviously large enough to meet that standard. However, gape size was likely an issue. According to Keeley and Grant [37], a 37 cm long salmonid can only consume a fish less than 7.5 cm in length. Thus, the 18 cm rainbow trout used in this study were at least 1.5 times larger than the brown trout could have eaten.

The lack of predation during the raceway part of this study prompted the movement of the fish to the pond. While predation did occur in the pond, it is difficult to interpret the unreplicated results. Although the rainbow trout were initially reared with environmental enrichment prior to placement in the raceways, it is likely that any positive post-stocking effects from such enrichment were retained prior to placement in the pond after four weeks in the raceways [14,39]. However, the vertically-suspended environmental enrichment used in this study appears to have minimal impact on predator avoidance, given the similar survival percentages from each treatment group after fish placement in the pond. Other studies have shown improvements in post-stocking survival of fish reared in environmental enriched tanks compared to controls [7,40-43]. However, additional studies have observed either no effect of environmental enrichment on post-stocking survival or even decreased post-stocking survival of fish previously reared using environmental enrichment [7,15,44-46].

Although predation on the rainbow trout in the pond is assumed to be the reason for their lack of recovery, it is possible, although unlikely, that the fish died from disease or unknown factors. It is also extremely unlikely that any of the unrecovered fish died from starvation, given the short duration of the study and the abundance of natural food in the pond [47,48]. Although direct predation of the rainbow trout in the ponds was not observed, the most probable predators were great blue herons and mink. Other predators were present, but at 18 cm, the rainbow trout in this study were beyond the preferred prey size of belted kingfishers [49] and below the size of prey preferred by osprey [50,51]. However, the rainbow trout were within the size preferred by great blue herons [52,53] and mink [54,55] which are frequently observed at the hatchery.

Conclusion

In conclusion, the use of vertically-suspended environmental enrichment did not appear to impact predator avoidance in this study. However, these results should be interpreted with considerable caution due to the relatively small level of predation during the raceway portion of this study and the lack of replication during the pond portion. Future experiments should ensure that the predators and prey used are appropriately-sized, as well as possibly live feed-train predator fish prior to the start of the study.

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