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Research Article

Rainbow Trout Locations in a Circular Tank Containing Vertically-Suspended Environmental Enrichment

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Abstract:

This study observed the locations of individual juvenile rainbow trout in a circular rearing tank during exposure to vertically-suspended environmental enrichment. The fish were either naïve (no prior experience with enrichment) or experienced (reared previously with vertically-suspended enrichment). One fish at a time was initially placed into a barren circular tank and the location of the fish in the tank was recorded every hour. After four hours, enrichment was added to the tank and location observations continued hourly for the next four hours. No significant difference in location was observed between naïve and experienced fish either with, or without, the presence of vertically-suspended environmental enrichment. However, regardless of the presence or absence of environmental enrichment, the tank location containing the spray bar had a significantly higher location frequency with both the naïve and experienced fish combined compared to other tank locations. While the results of this initial study may not be similar to those when larger numbers of fish are used during hatchery rearing, they none-the-less provide a foundation for further experimentation.

Keywords: Rainbow trout, *Oncorhynchus mykiss*, Environmental enrichment, Behavior.

Introduction:

Environmental enrichment is the inclusion of structure into otherwise barren hatchery rearing tanks [1]. Adding materials to tanks can interfere with routine fish culture activities and also increase the risk of disease [2-8]. However, these issues are greatly reduced in circular tanks when the structure is vertically-suspended [9].

Improvements in trout growth and feed conversion ratio due to vertically-suspended environmental enrichment have been widely reported [10-17]. The reason, or reasons, for the hatchery-rearing benefits associated with vertically-suspended structures is unknown. Environmental enrichment affects fish behavior [1,18], and behavioral changes due to environmental enrichment could be improving growth by reducing stress [1,19-21]. Vertically-suspended structures create areas of reduced velocities and Kientz and Barnes [10] hypothesized that fish use these areas to escape the relatively high constant water velocities required for tank self-cleaning [9,10,22,23].

There have been no studies documenting the behavior of fish in tanks containing vertically-suspended environmental enrichment. Even rudimentary information would provide some indication of how such structures are improving trout growth. Thus, the objective of this experiment was to evaluate the response, in relation to in-tank location, of rainbow trout *Oncorhynchus mykiss* exposed to vertically-suspended environmental enrichment.

Methods:

This experiment was conducted at McNenny State Fish Hatchery in Spearfish, South Dakota, USA using degassed and aerated well-water (constant temperature 11°C; total hardness as $CaCO_3$, 360 mg L^{-1}; alkalinity as $CaCO_3$, 210 mg L^{-1}; pH, 7.6; total dissolved solids, 390 mg L^{-1}) in a 2,000-L circular tank (1.8 m diameter × 0.8 m deep; 0.6 m water depth). The tank was covered (Walker et al., 2016), and was either barren or contained an environmental-enrichment array of four vertically-suspended aluminum angles (2.5-cm wide on each angle side × 57.15-cm long) as described by Krebs et al. (2018) (Figure 1). The angles were arranged so that the angled portion faced into the direction of water flow [12,24].

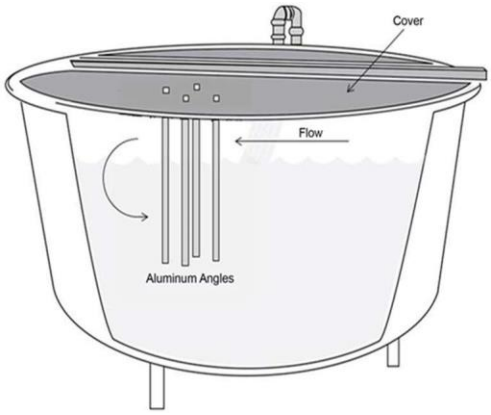

Figure 1. Circular tank with suspended array of four aluminum angles, with the peak of the angle facing in the direction of the water flow Juvenile Shasta strain rainbow trout (mean ± SE, weight 25.0 ± 2.2 g, length 134.4 ± 3.6 mm) were used in this experiment. The trout were either naïve (with no prior exposure to vertically-suspended environmental enrichment) or experienced (previously reared with vertically-suspended environmental enrichment). A total of eight fish were used, four naïve and four experienced (N=4). At 07:30, A single fish was placed into the tank with no enrichment and allowed to acclimate for 30 minutes. Observations were then recorded hourly for the next four hours. After four hours, vertically-suspended environmental enrichment (four aluminum angles) were added to the tank. After another 30-minute acclimation period, observations were again recorded hourly for the next four hours.

The experimental tank was divided into four quadrants (Figure 2). A video system with multiple cameras (Lorex LBV2531W, Lorex Technology Inc., Markham, Ontario, Canada) was attached to the tank cover. The location of the fish was obtained by recording a 15 second video at each hourly observation. Fish were fed (1.5mm Protec Trout, Skretting USA, Tooele, Utah, USA) twice each day at 9:45 am and 1:45 pm by hand. At the end of the observational period (16:00, nine hours after placement in the tank), the trout was removed from the experimental tank and measured (total length) to the nearest 1 mm and weighed to the nearest 0.1 g.

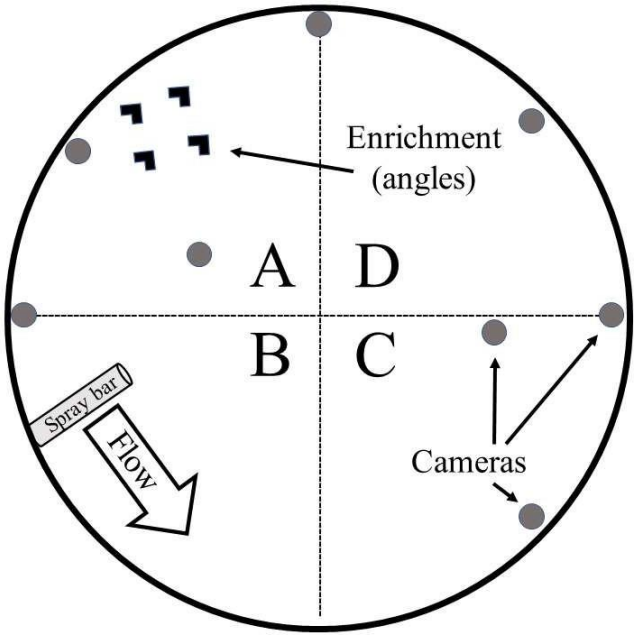

Figure 2. Tank zones and locations of vertically-suspended environmental enrichment, cameras, and the hatchery spray bar (incoming water).

Data were analyzed using SPSS (24.0) statistical program (IBM Corporation, Armonk, New York, USA). A weighted-cases chi-squared test was used to compare fish locations of either naïve or experienced fish in barren or enriched scenarios. Location preference among all fish was analyzed with a one-way ANOVA and Tukey HSD post-hoc test. Significance was predetermined at $p < 0.05$

Results:

The preferred tank location was not significantly different for naïve fish in either barren or enriched environments (χ^2 = 0.892; p = 0.827; Table 1). In addition, tank location preferences for experienced fish between barren or enriched environments were also not significantly different (χ^2 = 1.178; p = 0.758). There were also no significant location differences between the naïve and enriched fish when barren and enriched scenarios were combined (χ^2 = 4.458; p = 0.216). However, the location containing the spray bar (B), had a significantly higher location frequency with both the naïve and experienced fish combined compared to the other three zones (p = 0.000).

Table 1. Tank location frequencies of individual rainbow trout in circular tanks either with or without the presence of vertically-suspended environmental enrichment. The fish were either naïve (no prior exposure to such enrichment) or experienced. Zones are sequentially lettered following the direction of water flow, with zone A containing the suspended enrichment. Numbers with different letters across a row are significantly different (p = 0.05).

		Zone					
Fish	Enrichment	A	B	C	D	χ^2	p
Naïve	Yes	2	9	2	3	0.892	0.827
	No	1	8	2	5		
Experienced	Yes	4	7	2	3	1.178	0.758
	No	5	8	2	1		
Naïve Experienced	Combined	3 9	17 15	4 4	8 4	4.458	0.216
Total		12 y	32 x	8 y	12 y		0.000

Image 1. Image from a camera of a fish in zone C.

Discussion:

The lack of effect of vertically-suspended environmental enrichment on rainbow trout location within a circular tank was unexpected. It has been hypothesized that trout would prefer the lower water velocity areas behind the suspended structure, with the lower velocity microhabitats more energetically profitable [10,11,25]. In streams, trout will typically occupy areas of low velocity, only darting into higher velocity areas briefly to feed water velocity is likely the most important determination of microhabitat selection [26-29]. While the rainbow trout in this study preferred the lower-velocity area directly behind the suspended structure they also preferred the same area even when such structure was absent [9,22,23]. Because this preferred area also contained the incoming water spray bar, it is possible that the turbulence created by the incoming water was a stimulus for trout location. Water turbulence can have substantial effect on fish behavior and habitat choice, and fish have been shown to prefer areas of unsteady flows [29-35]. Future research examining fish behavior with the suspended structure moved to different locations would be beneficial.

Making conclusions from single fish observations is an obvious limitation of this study. Fish tend to behave differently in groups as compared to individually [36-38]. In addition, observing and quantifying fish behavior can be very difficult and complex, especially in studies such as this where behavior is observed for time periods longer than an immediate reaction [39]. While it would be impossible to make behavioral observations of individual fish in tanks operating at full hatchery production levels, additional experimentation with larger numbers of fish would be desirable.

It is possible that the genetic strain of rainbow trout used in this experiment may have affected the results. The Shasta strain was one of the first rainbow trout strains to be cultured, is very domesticated,

and exhibits poor long-term survival when released into natural ecosystems [40-42]. In contrast, less-domesticated strains can be more difficult to rear in captivity and have shown the ability to survive, grow, and reproduce after stocking into recreational fisheries containing predators and competitors [43,44]. A less-domesticated rainbow trout strain with more inherent natural behaviors may be more attuned to the presence of structure in an otherwise barren tank.

The positive effects of vertically-suspended environmental enrichment on trout growth and feed conversion ratio is well-documented [10-15]. However, the mechanism by which vertically-suspended structures are creating these improvements is unknown. The results of this study suggest that behavioral responses may not be that important, with structurally-induced changes in circular tank velocity profiles more likely responsible for the increased rearing efficiencies [9,22,23].

In conclusion, the results of this study using individual rainbow trout indicates that although the fish have a clear location preference in circular tanks, this preference is not predicated on the presence of vertically-suspended environmental enrichment. Further experimentation with larger numbers of fish, different locations of suspended enrichment, and non-domesticated fish is needed.

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