Matthew J, et al., J Aquac Fisheries 2025, 9: 102
DOI: 10.24966/AAF-5523/1000102

HSOA Journal of
Aquaculture & Fisheries

Research Article

Use of Vertically–Suspended Environmental Enrichment during Intensive Rearing of Juvenile Bluegill

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Abstract

Vertically-suspended environmental enrichment is used to improve the structural complexity of fish rearing units. This study evaluated the effects of vertically-suspended metal rods as environmental enrichment in Recirculating Aquaculture System (RAS) circular tanks containing bluegill (*Lepomis macrochirus*). At the end of the 55-day experiment, ending tank weight, gain, and percent gain were significantly greater in unenriched tanks compared to those with vertically-suspended environmental enrichment. Feed conversion ratio was significantly lower in unenriched tanks as well. However, individual fish length, weight, condition factor, and specific growth rate were not significantly different between bluegill reared in tanks with vertically-suspended environmental enrichment and those reared in control unenriched tanks. These results indicate that vertically-suspended environmental enrichment does not improve bluegill growth, at least with the size of fish and enrichment used in this study.

Keywords: *Lepomis macrochirus*; RAS; Structure; Welfare

Introduction

Enriching the relatively sterile environments used during fish rearing can take many forms, including adding structure, changing color, or incorporating exercise [1-4]. While increasing structural complexity in hatchery rearing units is not difficult, adding materials to the units typically hinders removal of solid waste resulting in increased disease risks and labor [2,5-8]. To mitigate these problems, Kientz and Barnes [9] suspended structures vertically from the top of circular tanks, creating the first vertically-suspended environmental enrichment. This enrichment has been shown to not impact the hydraulic self-cleaning of circular tanks while improving growth and feeding efficiencies of a number of salmonid species [7,10-16].

Salmonids have also been the primary focus of other physical environmental enrichment research. The results have generally been positive, with increases in fish growth [17-19], increases in post-stocking survival [20,21], and the appearance of more natural behaviors [3,22-24]. However, with the increasing use of species from other families using recirculating aquaculture technology [25-27], the potential applications of environmental enrichment have increased. The rearing performance of pikeperch (*Sander lucioperca*) and sterlet (*Acipenser ruthenus*) was not impacted by the use of vertically-suspended environmental enrichment during Recirculating Aquaculture System (RAS) polyculture [28].

Bluegill (*Lepomis macrochirus*) are a member of the Centrarchidae family native to the eastern and central United States [29]. They have a short, compressed, oval-shaped body with large pectoral fins, making them exceptionally maneuverable. In the wild, juvenile bluegill prefer structurally-complex habitats with submerged woody debris and dense aquatic vegetation [29-36]. Because bluegill are a popular sport fish with recreational anglers, they are produced both extensively in ponds and intensively in tanks in hatcheries [27,37-39].

Typical hatchery rearing tanks are relatively sterile and devoid of structure [9]. Because bluegill prefer structural complexity, it was hypothesized that they would respond positively to the presence of environmental enrichment. Thus, the objective of this study was to evaluate the effects of vertically-suspended environmental enrichment during the intensive rearing of bluegill in circular tanks.

Materials and Methods

This experiment occurred at Cleghorn Springs Fish Hatchery, Rapid City, South Dakota, USA, using recirculated water (25.5° C, pH 7.3 ± 0.2 (mean ± SE), dissolved oxygen at 85-to-95% saturation, total ammonia nitrogen concentration ≤ 0.5 mg/L). Six, 2,000 L circular tanks (1.8 m diameter, 0.76 m operating depth) in the same recirculating aquaculture system were used. Three control tanks were void of any structure, while the other three tanks received vertically-suspended environmental enrichment (n = 3). The structure consisted of 32 vertically-oriented round aluminum rods, similar to those described by Kientz and Barnes [9] inserted into a 99 cm by 201 cm partial overhead tank cover similar to that described by Barnes and Durben [40], Barnes et al. [41], and Walker et al. [42]. The aluminum rods were spaced approximately 20 cm apart (Figure 1).

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Citation: Matthew J, Treft C, Voorhees JM, Fletcher B, Barnes ME (2025) Use of Vertically–Suspended Environmental Enrichment during Intensive Rearing of Juvenile Bluegill. J Aquac Fisheries 9: 102.

Received: January 21, 2025; **Accepted:** January 31, 2025; **Published:** February 07, 2025

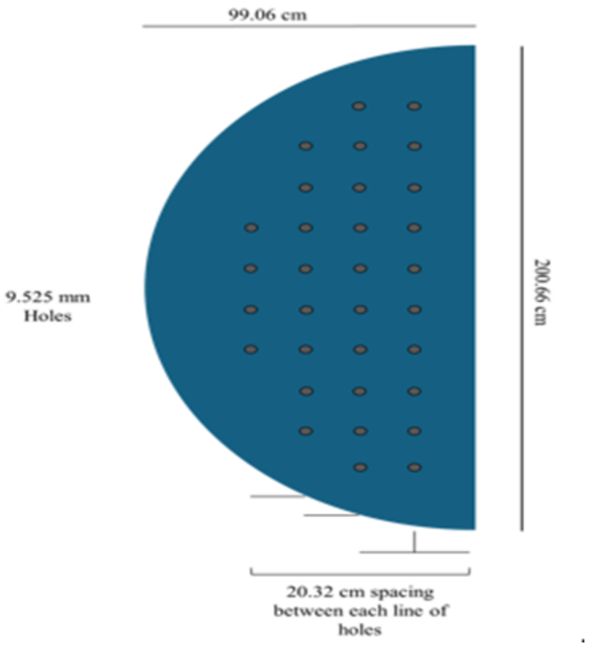

Figure 1: Top view of the partial tank cover used to suspend aluminum rods for vertically-suspended environmental enrichment in a 200-cm diameter circular tank containing bluegill. Hole locations indicate where aluminum rods were inserted.

On 9 June 2022, approximately 6,000 juvenile bluegill (mean ± SE; initial weight 13.8 ± 0.0 g, length 84 ± 0 mm, n = 60) were evenly distributed between the six tanks, with each tank receiving approximately 1,000 fish (initial tank weight = 13.6 kg). Each tank was equipped with a mini belt feeder (Fiap Standard 3kg, 12# Belt Feeder, FIAD Gmbtt, Ursen Sollen, Germany) that dispensed feed for 12 hours. Food was increased weekly based on body weight percentage. During the duration of the study, each tank received 33.5 kg of 1.0 mm sinking feed (Oncor RC, Skretting USA, Tooele, Utah, USA).

At the end of the study on 2 August 2022 (55 days) total tank weight was obtained by weighing the entire tank biomass to the nearest 0.1 kg. Fifteen random fish from each tank were also individually weighed to the nearest 0.1 g and measured (total length) to the nearest 1.0 mm.

The following equations were used:

Gain = final tank weight – initial tank weight

Condition factor (K)= [weight (g)/total length]

Feed conversion ratio (FCR) = food fed / weight gain

SPSS (24.0, IBM, Armonk, New York, USA) statistical program was used for data analysis. Students t-tests were used to compare effects between the treatments. Because the tanks were the experimental unit and not the individual fish (n = 3), mean length and weight values from the fifteen randomly sampled fish were used for analysis. Significance was predetermined at $P < 0.05$.

Results

Biomass in all of the tanks nearly tripled by the end of the experiment. Tank ending weight, gain, and percent gain were significantly greater in the control (unenriched) tanks compared to the tanks with vertically-suspended environmental enrichment (Table 1). Feed conversion ratio was significantly less in the control tanks. Mortality was relatively low at approximately one percent and was also not significantly different between the treatments. Individual fish length, weight, specific growth rate, and condition factor were not significantly different between the control and enrichment treatments (Table 2).

	Enriched		
	Yes	No	P
Final weight (kg)	40.1 ± 0.2 y	42.0 ± 0.3 z	0.009
Gain (kg)	26.5 ± 0.2 y	28.4 ± 0.3 z	0.009
Gain (%)	194.9 ± 1.3 y	208.6 ± 2.6 z	0.009
Feed conversion ratio	1.26 ± 0.01 y	1.18 ± 0.01 z	0.008
Mortality (%)	0.89 ± 0.13	1.12 ± 0.04	0.090

Table 1: Mean (± SE) final tank weight, gain, feed conversion ratio (FCR) a, and mortality from tanks of bluegill reared either with (enriched) or without (not enriched) vertically-suspended environmental enrichment. Means with different letters across a row are significantly different (n =3; P < 0.05).

a FCR = food fed / gain

	Enriched		
	Yes	No	P
Length (mm)	114 ± 2	117 ± 5	0.651
Weight (g)	38.7 ± 1.9	39.1 ± 2.8	0.903
Specific growth rate	1.87 ± 0.09	1.88 ± 0.12	0.922
K	2.61 ± 0.07	2.47 ± 0.15	0.471

Table 2: Mean (± SE) final individual fish length, weight, specific growth rate (SGR)a, and condition factors (K)b for bluegill reared with (enriched) or without (not enriched) vertically-suspended environmental enrichment (n = 3).

a SGR = 100 * (ln (end weight) – ln (start weight)) / (number of days)

b $K = 10^5 * (\text{fish weight}) / (\text{fish length})^3$

Discussion

The results of this experiment contradict the observations of numerous other studies evaluating vertically-suspended environmental enrichment with salmonids [7,9,11,12,14,15,43,44]. Kientz and Barnes [9] first described the significant improvement on rainbow trout (*Oncorhynchus mykiss)* rearing performance using vertically-suspended environmental enrichment. However, a smaller number of studies have found no improvement in the rearing performance of salmonids cultured with vertically-suspended environmental enrichment [13,45-47]. There could be species-specific differences in response to vertically-suspended environmental enrichment, even within the same family of fish.

There has been only one study evaluating vertically-suspended environmental enrichment on species other than salmonids. During polyculture in a recirculating aquaculture system, pikeperch and sterlet growth and morphology were not significantly impacted during rearing with vertically-suspended environmental enrichment [28]. Bluegill differ greatly from these two fish species and are also dramatically different than salmonids. For example bluegill prefer warm, lentic water with rooted aquatic vegetation for cover [29,33].

The positive effects of vertically-suspended environmental enrichment have been attributed, in part, to alteration of in-tank velocities [48-50]. In tanks with substantial rotational velocities, the area immediately behind the vertically-suspended environmental enrichment may be proving lower-velocity microhabitats allowing fish to decrease energy expenditures when not feeding [9]. These decreased velocities would likely be beneficial for bluegill, given their preference for lentic, low-velocity environments [33]. However, in the present study, water velocities in both the control and enriched tanks were minimal. Although in-tank velocities were not measured, with the minimal water movement in each tank there was likely little difference in water velocity in-front or behind the enrichment structure.

The lack of impact from environmental enrichment seen in this study could be because of its relatively-short 55-day duration [4]. In addition, the bluegill used in this experiment were relatively-older juveniles. Juvenile bluegill growth, while entirely dependent on water temperature and food availability, is separated into an initial, 30-to-40 day rapid phase followed by a much slower phase [48]. It is likely that the larger juvenile bluegills used in this experiment had already surpassed their rapid growth phase, resulting in slow growth over the relatively-short duration. After hatching and up to a length of approximately 5 mm, bluegill larvae leave their nests and migrate to open water to feed on zooplankton or other surface level prey [34]. After 4-to-6 weeks of feeding in open water, the small fish return to the littoral zone [34]. Upon reaching a length of 75 mm, bluegill move into open water for the remainder of their life cycle [34]. The bluegill used in this study were 84 mm, indicating that they would likely prefer open water void of structural complexity [34].

It is possible that this study had too much vertically-suspended environmental enrichment (too many suspended rods). Huysman et al. [46] observed that increasing the array of vertically-suspended rods from nine to 15 negatively affected salmonid growth. In the wild, juvenile bluegills use areas of low velocity like submerged vegetation for protection from predators [33]. However, an excessive abundance of vegetation results in an inhibition of prey and predator response [33].

Further studies using vertically-suspended environmental enrichment during bluegill rearing is needed. Specific experiments examining enrichment needs of different bluegill life stages, vertically-suspended array sizes, and longer durations should be conducted. In addition, it would be beneficial to rear the bluegill with environmental enrichment in the presence of live prey, given the positive correlation between prey presence and rearing success of juvenile bluegill [51].

Acknowledgement

We thank Shaylee Martling and Kaitlyn Williams for their assistance with this study.

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