Journal of Aquaculture and Fish Health Vol. 12(2) - June 2023
P-ISSN: 2301-7309 / E-ISSN: 2528-0864
doi : 10.20473/jafh.v12i2.34474

Impact of Water Source and Quality on Survival, Growth and Health of *Clarias gariepinus* Fingerlings Reared in Indoor Concrete Tanks

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Received : 2022-03-22
Accepted : 2022-08-14

Keywords :
Clarias gariepinus, Concrete tank, Health, Water source

Abstract

This experiment investigated the impact of two water sources and their quality on the survival, growth, and health of *Clarias gariepinus* fingerlings reared in indoor concrete tanks. 400 fingerlings of mean weight 15.33±3.47 g and total length 12.63±1.00 cm (mean ± standard deviation) were randomly distributed into four concrete tanks of 12 m^3 capacity each. Water quality was analyzed bi-weekly throughout the study duration. Growth parameters such as mean weight gain (MWG), specific growth rate (SGR), and feed conversion rate (FCR) were calculated using standard procedures. At study termination, duplicate groups per treatment were assessed for survival rate and a health status check was determined by a hematological evaluation and microscopic examination of parasitic incidence. Results indicated that fish reared in water sourced from a bore-hole [BH] performed comparatively significantly better in growth ($p < 0.05$) than fish in water from an earthen pond [EP] as the MWG stood at 294.05±79.17 g for the former against 211.03±54.62 g for the latter with the survival rates for both treatments being in excess of 90%. Additionally, fish reared in EP presented with a higher infestation load of *Trichodina* spp., although there was no significant difference ($U = 7$, $p > 0.05$) between fish reared in EP and BH treatments with regards to their packed cell volume levels and white blood cells. The outcome of this study shed light on the impact a water source can have on the growth and health status of *C. gariepinus* with a recommendation for microbiological analysis of water supply from open/surface systems before usage for the African catfish aquaculture.

INTRODUCTION

Water supply for aquaculture are classified mainly into two, namely, surface water and groundwater (Olopade, 2013). In Nigeria, both water sources are utilized for the culture of *Clarias gariepinus*. According to the United States Environmental Protection Agency (2006), water quality standards vary significantly due to different environmental conditions, ecosystems, and intended human uses.

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The health and subsequent growth of fish are directly related to the quality of water in which they are raised. In general, factors affecting fish growth and production in aquatic systems can be classified as physical, chemical /biochemical, or a combination thereof. Temperature is a physical property of water that is important to fish production and growth while important chemical parameters include pH and dissolved oxygen (Viadero, 2005).

Health and survival were one of seven future research priorities highlighted by Slater *et al*. (2018) with the likelihood to yield the greatest impact on improving and increasing commercial aquaculture outputs within the decade. In recent years, fish welfare has become a topic of interest so much so that animal rights groups have expressed their concerns on the welfare of farmed fish resulting in scientific, public, commercial, and governmental discussions (Ashley, 2007; Martins *et al*., 2012; Berlinghieri *et al*., 2021).

As such, Del Rio-Zaragoza *et al*. (2021) have proposed that hematological parameters testing during the whole growing out season represents a useful tool to assess overall fish health status. Hematological parameters are widely used measurable factors that aid in monitoring the health status of farmed fish. The use and validation of fish health monitoring tools have become increasingly evident due to the expansion of aquaculture. The complete blood cell count (CBC) is an important diagnostic tool that can be used to appraise the health status of fish in response to changes related to nutrition, water quality, and disease in response to therapy (Fazio, 2019).

Therefore, the objectives of this study were to; firstly, evaluate the impact of two available water sources and their quality on the growth and survival of *C. gariepinus* fingerlings reared in indoor concrete tanks, and in addition, analyze the hematological parameters and parasite infestation of samples taken from each replicate from both treatments when they had attained juvenile life stage.

METHODOLOGY

Place and Time

This study was carried out at the Grow-Out Unit in Badore Research Centre of the Nigerian Institute for Oceanography and Marine Research, Lagos from December 2020 to February 2021.

Research Materials

The equipment used in this study included Mettler Toledo electronic balance (ME1002E) determined to an accuracy of 0.01 g and Wildco® fish measuring board (118-B30) to the nearest 0.1 cm respectively. An Olympus binocular microscope, mercury-in-glass thermometer, Pond Lab test kit 200, and LaMotte kit (code 4447-01) were also utilized.

The materials used were a set of four indoor 12 m^3 capacity rectangular concrete tanks depicted in Figure 1. Two water sources were utilized; a 31 x 31 x 2 meters tidal/rain-fed earthen pond and an industrial bore hole. One thousand *C. gariepinus* fingerlings (mean weight 8.21 ± 0.65 g and total length (TL) 10.82 ± 0.27 cm) were obtained from a reputable supplier located at Ikorodu, Lagos State, and conveyed to Badore Research Centre, Nigerian Institute for Oceanography and Marine Research, Lagos, Nigeria in plastic containers.

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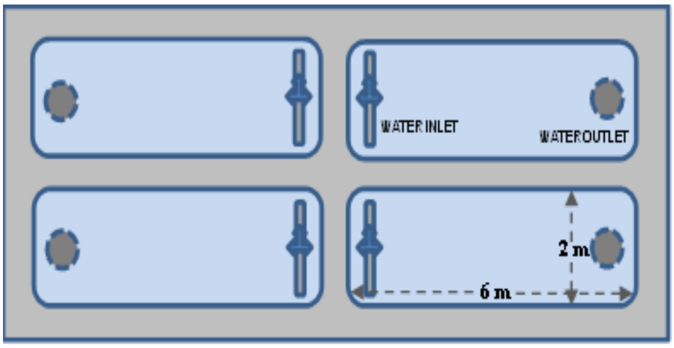

Figure 1. Schematic diagram of tanks showing inlets, outlets, water sources, and dimensions.

Research Design

Fish were left to acclimatize in one tank for one week prior to the experimental trial which is the minimum period recommended by Gabriel *et al*. (2004). The experiment comprised two treatments, each with two replicates. Treatments 1 and 2 were water sourced from an earthen pond and industrial bore-hole respectively.

Following acclimatization, random allotment of 400 graded African catfish fingerlings into four tanks was carried out at a stocking rate of 10 fingerlings/m^3 according to Edward *et al*. (2010) for the highest mean weight gain, specific growth rate, relative growth rate, and survival. Initial sample measurements undertaken to commence the experiment averaged 15.33±3.47 g for weight and 12.63±1.00 cm for total length.

Fish were fed a commercially available diet containing 45% protein and 10% fat for the first four weeks while in the co-concluding month of the study, they were fed 42% protein and 12% fat, all at 7% body weight.

Work Procedure

Fish Samplings

Fortnightly, weight and length assessments of study samples were carried out. The dietary feeding rate was then recalculated using their new mean weight and the feeding was adjusted in accordance to the increased weight of the fish.

Water Quality Measurement

Water samples from each treatment were tested for temperature using a mercury-in-glass thermometer while pH, dissolved oxygen, ammonia, nitrite, and nitrate were analyzed with Pond Lab test kit 200. LaMotte kit (code 4447-01) was used for the iron test.

Fish Health Assessment

Blood samples were collected from the caudal veins of sampled fish (300 - 400 g) using 2 ml disposable syringes and hypodermic needles, and then discharged into separate EDTA (Ethylenediamine tetra acetic acid) tubes for assessment at the Veterinary Medicine Laboratory of the University of Ibadan, Oyo State, Nigeria. Methods found in Lawrence *et al*. (2020).

Swabs were taken from the skin, gills, intestine, stomach, and liver of the fish at study termination as described in Aly *et al*. (2020), and examined using Olympus binocular microscope.

Survival Rate

Survival rate (SR) is the percentage of *C. gariepinus* that were alive and counted at termination of study. Calculation was modified from Azhar *et al.* (2021) as follows:

$$SR = \frac{Nf}{Ni} \times 100\%$$

Where:
N_f = final fish number
N_i = initial fish number

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Mean Weight Gain

The fish fresh weight gain (WG) was calculated as the difference between the final weight of the fish at the end of the experiment and the initial weight in grams.

Mean Length Gain

Fish increment in length (LG) was calculated as the difference between the final length of the fish at the end of the experiment and the initial length in centimeters.

Average Daily Weight Gain

The formula for average daily weight gain (ADWG) was obtained from Panase and Mengumphan (2015).

$$\text{ADWG} = \frac{\text{final weight} - \text{initial weight}}{\text{days of culture}}$$

Average Daily Length Gain

The formula of average daily length gain (ADLG) was obtained from Panase and Mengumphan (2015).

$$\text{ADWG} = \frac{\text{final length} - \text{initial length}}{\text{days of culture}}$$

Specific Growth Rate

This is the mean percentage increase in body weight per day over a given time interval.

$$\text{SGR} = \frac{\text{LnWt} - \text{LnWo}}{\text{t}} \times 100\%$$

Where:
Wt = final fish weight (g)
Wo = initial fish weight (g)
t = study period (days)

Feed Conversion Rate

The efficiency of a feed is normally measured by the amount necessary to produce a unit weight of fish.

$$\text{FCR} = \frac{\text{feed given (g)}}{\text{wet weight (g)}}$$

Data Analysis

SPSS IBM Statistics version 20.0 was utilized for the analysis of data following the model of a Mixed-Design test (Thorarensen *et al.*, 2015). For the fish growth assessment, analysis was therefore done for a combination of one between the subjects' factor (water sources) and one within the subjects' factor (five sampling times). All assumptions for the test except Mauchly's Test of Sphericity were met so the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity for the statistically significant interaction at the significance value of $p < 0.05$.

Parasite infestation intensity between the two treatments in this study was compared while the fish blood parameters analyzed at study termination were subjected to the non-parametric Mann-Whitney U tests following checks that the requisite assumptions for the test were met. A probability level of 0.05 was used to determine significance.

RESULTS AND DISCUSSION

Survival Rate

The mean survival rates which were above 90% for *C. gariepinus* from the two treatments are shown in the boxplots in Figure 2 with their medians being 96.5 and 95 percent for the earthen pond and bore-hole treatments respectively which are similar to the survival rates obtained from aquaculture studies carried out in indoor concrete tanks where survival ranged from 85 to 92.5% for Dutch *Clarias* fry (Olanrewaju *et al.*, 2009). Ovie and Eze (2013) in a study comparing the percentage survival of *C. gariepinus* fingerlings in indoor (65±25.98 to 80±17.32%) and outdoor (92±0.50 to 93±2.00%) concrete tanks, obtained a higher performance in the outdoor tanks, it was reported that the variation was not statistically significant ($p > 0.05$).

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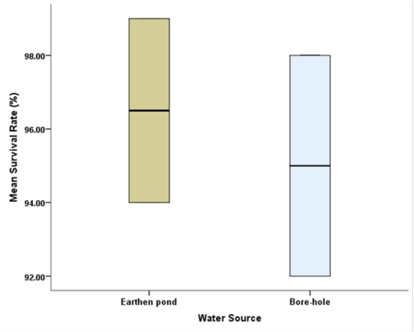

Figure 2. The mean survival rates of *C. gariepinus* from the two treatments.

Fish Growth Performance

C. gariepinus growth curves established for each water source treatment are presented in Figure 3. There was a significant interaction between sampling times and treatment, F (1.73, 65.75) = 347.92, p < 0.05. The result obtained reiterates the emphasis by Boyd and Tucker (1998) that the efficient production of fish in aquaculture systems depends on a suitable environment for them to grow. Ada *et al*. (2012) validate the preference of water sourced from a borehole to water pumped from an open earth pond for improved fish culture.

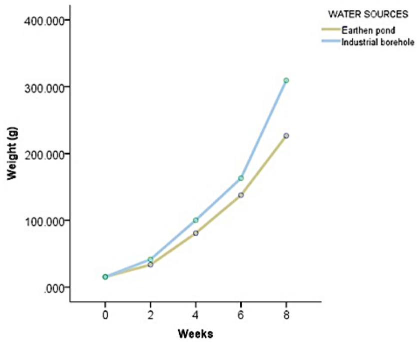

Figure 3. Growth curves of *C. gariepinus* reared in water from different sources.

Comparative Growth Indices

The growth indices shown in Table 1 demonstrates that fish reared in water sourced from the industrial borehole performed better and were a more suitable environment for faster weight gain and better feed conversion rate.

Table 1. Growth performance of *C. gariepinus* reared in water from earthen pond and borehole.

Growth Parameters	Tidal/Rain-fed Earthen Pond	Industrial Borehole
Initial mean weight (g)	15.33±3.52	15.33±3.52
Final mean weight (g)	226.36±54.51	309.38±79.09
Average daily weight gain (g)	3.77±0.98	5.25±1.41
Mean weight gain (g)	211.03±54.62	294.05±79.17
Initial mean length (cm)	12.63±1.00	12.63±1.00
Final mean length (cm)	30.13±1.96	33.1±2.15
Average daily length gain (cm)	0.31±0.04	0.37±0.04
Mean length increment (cm)	17.5±2.20	20.47±2.37
Weight gain (%)	1377±476	1918±679
Specific growth rate (g) [%]	5±0.99	5±0.00
Feed conversion rate	1.24	1.03

Note: Values are Mean ± SD of two replicates.

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In a socio-economic study by Ebukiba and Anthony (2019) which evaluated the percentage of respondents that depended on bore-holes as a water source for fish farming versus other sources, it was determined that 55% utilized bore-hole water, 5% pumped from streams/rivers while 25% made use of earthen ponds only; the last two being open/surface waters.

In analyzing the SGR and FCR of *C. gariepinus* studied in concrete tanks, findings indicated that the fish utilized by Goda *et al*. (2007) presented with lower SGR of 1.52 – 1.93 and higher FCR of 2.31 – 3.32 across all treatments than what was achieved in this experiment. These differences may have been influenced by their use of 3% body weight feeding for 6 days week^{-1} against the 7% body weight daily feeding used in the current study.

Water Quality Parameters

Reference values within the documented desirable range along with the summarized data of water quality from the two sources used are presented in Table 2.

Table 2. Summary of water quality parameters from pond and borehole with reference values.

Parameters	Treatment		Optimum Range
	T1	T2	
Temperature (°C)	28-29	28-29	25-32[1]
pH	7	7	6.5-9.5[2]
DO (mg/L)	2.4	1.2	5-6[3]
Ammonia (mg/L)	1.0-5.0	0.2-1.0	0-0.5[4]
Nitrite (mg/L)	0-4	0-8	0-1[5]
Nitrate (mg/L)	0.2-80	2.0-80	0-140[6]
Iron (mg/L)	0.1-0.3	0.2	0-0.1[4]

Note: [1]Dupree and Huner (1984), [2]Boyd (2017), [3]Stone and Thomforde (2004), [4]Stone *et al*. (2013), [5]Roques *et al*. (2013), [6]Schram *et al*. (2012).

Temperature is an important parameter that impacts fish growth and metabolism. The temperature range which was 28-29 °C for both treatments fell within the temperatures of between 25.0 and 32.0 °C, reported to be best for warmwater fish by Dupree and Huner (1984). pH was consistently at 7 for the two treatments and is regarded as an optimal state for the growth and welfare of cultured fish as Boyd (2017) has noted that most of the problems with water quality such as health deterioration of aquaculture animals during culture arise from less-than-optimal supply water for the production systems and inadequate water exchange rate.

The dissolved oxygen (DO) was lower in water supplied from the borehole at 1.2 mgL^{-1} than in water from the open earth pond which was 2.4 mgL^{-1}, notwithstanding, the *C. gariepinus* in the BH treatment presented fish with better growth probably because this species, DO is not a limiting factor as they can utilize atmospheric oxygen due to their possession of arborescent organs otherwise known as labyrinth organs which allows for aerial breathing (Haylor, 1989; Belão *et al*., 2011).

Other key parameters, namely ammonia, nitrite, and nitrate, showed no particular trend. For instance, ammonia was higher in the earthen pond (EP) treatment with a range of 1.0-5.0 mgL^{-1} while nitrite was wider ranged in the BH treatment at 0-0.8 mgL^{-1}. Since ammonia is dangerous when water pH exceeds 7, it is assumed that the values obtained in this study were tolerable to the fish. Additionally, warm water fish are less sensitive to ammonia and catfishes have been reported as hardy fish with the ability to adjust to up to 5 mg/L of ammonia (Stone *et al*., 2013).

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Nitrite produced during nitrification through ammonia utilization by nitrifying bacteria exceeded the threshold concentration of 0.6 mg/L recommended by Roques *et al*. (2013) in the rearing water of *C. gariepinus* while the nitrate present in both treatments in this study was below the nitrate threshold concentration of 140 mg/L, advised by Schram *et al*. (2012) not to exceed for *C. gariepinus*. The mean concentration of iron for EP and BH was 0.2 mg/L and so was higher than the acceptable value of 0.1 mg/L for most fish as reported by Stone *et al*. (2013).

The comparative assessment of water quality from a freshwater tidal earthen pond and borehole-sourced concrete tanks have been studied by Davies and Ansa (2010) with some similar findings such as higher DO and ammonia found in the ponds than in the tanks. The suitability of water sources and those considered high-quality sources for aquaculture had been highlighted by Swann (1993) while Swann (1997) indicated that water was a limiting factor in fish production and that many of the negative chemical and environmental factors associated with most operations had their origins in the source of water used. Overall, the quality of water from both ground and surface in this study did not result in outwardly visible aberrations on the catfish thereby reaffirming the hardiness of the African catfish.

Microscopic Examination

From the examined swabs of exterior and interior organ surfaces, only the skins and gills of the fish reared in earthen pond sourced water were found to have a higher incidence of the ectoparasitic ciliate *Trichodina spp*. For the fish reared in borehole sourced water, the *Trichodina spp.* were only seen in the gills at a lower infestation level. Results obtained (Table 3) showed that the water type influenced parasite infestation intensity.

Table 3. Means comparison of *Trichodina spp*. infestation.

Water Source		Gill Infestation	Skin Infestation
	Mean	65.8750	5.0000
Earthen pond	N	8	8
	Std. Deviation	105.15354	7.38725
	Mean	2.6250	.0000
Borehole	N	8	8
	Std. Deviation	4.37321	.00000
	Mean	34.2500	2.5000
Total	N	16	16
	Std. Deviation	78.96708	5.66863

The outcome of the microbial evaluation was in consonance with Plumb and Hanson (2010) that pathogens are often endemic in surface waters especially in warm-water fish culture although Madsen *et al*. (2000) stated that most trichodinids are not pathogens except when the relationship of host/parasite/ environment is broken by such things as poor water quality, then a proliferation of these trichodinids would become responsible for disease outbreaks and severe epidermal lesions.

From this study, it is safe to assume that the water quality parameters of both EP and BH where iron and nitrite, for instance, exceeded the acceptable limits of 0.1 mg/L and 1 mg/L respectively for most fishes were not high enough for *C. gariepinus* to result in disease within the experimental systems or skin lesions.

Conversely, in a study by Suliman *et al*. (2021) where there was a substantial deterioration of fish pond water of *Oreochromis niloticus*, sampled water showed low oxygen, high ammonia, and nitrite with the examined fish presenting with severe alterations, blood hemorrhage, the fusion of secondary lamella, erosion and

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mucus secretions of the gills and the disease severity resulting in the death of some individuals. The histopathology of the fish gills indicated ectoparasites, one of which was *Trichodina*.

The trichodinids preference for gills or skin has been corroborated in studies on carp (Nikolić *et al*., 2003) and a mugilid, *Liza abu* (Al-Saadi, 2014). Other works include Tang and Zhao (2011) and Wang *et al*. (2018) where freshwater fish species, namely *Cyprinus carpio*, *Carassius auratus,* and *Micropercops swinhonis* were found to have gill infestations of different species of *Trichodina*.

Hematological Evaluation

Differences in blood parameters, i.e., packed cell volume, hemoglobin concentration, red blood cells, white blood cells, thrombocyte count, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and lymphocytes were calculated for fish that were reared in EP and BH treatments and are shown in Table 4. Eosinophils were not recorded in the fish studied.

Table 4. Blood composition of *C. gariepinus* reared in water sourced from EP and BH.

Blood Parameters	Treatment 1 – EP	Treatment 2 – BH
Packed Cell Volume (%)	23.67±2.31	27.33±2.89
Hemoglobin concentration (g%)	7.53±0.65	8.97±0.92
Erythrocytes [red blood cells] (x 10^6 / mm^3)	10.28±3.18	13.02±5.31
Leukocytes [white blood cells] (x 10^3 / mm^3)	6.00±2	7.33±1.01
Thrombocytes [platelets] (x 10^6 / mm^3)	4.67±0.58	8.00±3.46
Mean Corpuscular Volume (fl)	23.67±9.07	23.00±10.15
Mean Corpuscular Hemoglobin (pg)	7.33±3.21	7.33±3.06
Mean Corpuscular Hemoglobin Concentration (%)	32.00±0.00	32.00±0.00
Lymphocytes (%)	30.00±2	24.33±2.08
Neutrophils (%)	68.33±1.53	74.67±2.08
Monocytes (%)	1.67±0.58	1.00±0.00
Eosinophils (%)	---	---

Note: Values are Mean ± SD of three replicates.

A Mann-Whitney U test showed that for both the packed cell volume and white blood cells there was no significant difference (U = 7, $p > 0.05$) between fish reared in EP and BH treatments. Also, there was no significant difference at $p > 0.05$ between fish reared in EP and BH treatments in terms of hemoglobin concentration, and the mean ranks for EP and BH treatments were 2.33 and 4.67 respectively. The null hypothesis was again retained with regard to the erythrocyte count (U = 5, $p > 0.05$) and thrombocytes (U = 6.5, $p > 0.05$) for the treatments.

In agreement to Burgos-Aceves *et al*. (2010) and as can be seen in the outlined blood composition in the preceding table, ichthyo-hematological studies have practical significance, which is said to be due to the functional polyvalence of the blood system and its high reactive mobility. In this study, even though there were some notable differences in the blood parameters such as the packed cell volume, erythrocytes, thrombocytes and lymphocytes of the experimental fish drawn from the two treatments, there were not statistically significant at $p < 0.05$.

A similar study to evaluate the water quality of the River Nile by Osman *et al*. (2018) utilized the blood of Nile tilapia and African catfish as biomarkers. Although the content of erythrocytes and leukocytes, along with the reference values for most fish species have not yet been established as noted by Burgos-Aceves *et al*. (2010), characterization of some blood parameters of the African catfish has been carried out by Erhunmwunse and Ainerua (2013) and Shlenkina *et al*. (2019).

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Toxicological studies by Kreutz *et al*. (2011) where following a short-term exposure of *Rhamdia quelen* to sublethal concentrations of a glyphosate-based herbicide resulted in the catfish presenting with significant reductions in blood erythrocytes, thrombocytes, lymphocytes and total leukocytes, thereby further demonstrating the observation by the authors that the values of red and white blood cells in fish depend on, among other factors, the hydro-chemical regime and water pollution. Besides, Santos *et al*. (1991) found that metabolically active and intact erythrocytes enhanced thrombocyte activation and recruitment which may have been the scenario with the BH treatment which presented with a comparatively higher red blood cell count and also a higher platelet count.

CONCLUSION

The presented results shed light on the effect a water source and its quality can have on the growth and health of *C. gariepinus*. The supply of water from open/surface systems for raising the African catfish is more likely to result in the inadvertent introduction of a ubiquitous, obligate, and opportunistic aquatic ectoparasite, e.g., *Trichodina*, to the receiving production systems than the use of closed/underground water systems. It is recommended that a microbiological analysis of water supply from open/ surface systems be carried out before usage for the African catfish aquaculture.

ACKNOWLEDGEMENT

The authors are grateful to the laboratory technologist, Mr. E. S. Afolabi for the parasitological evaluations at the Fish Disease Laboratory, Badore Research Centre, Nigerian Institute for Oceanography and Marine Research, Lagos.

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