# Influence of the Starvation Period on the Technological Performance of Juvenile Carp in a Recirculating Aquaculture System

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**Abstract**
Compensatory growth relates to a period of intensified feeding, typically following a brief period of starvation, and represents a technological opportunity to achieve the planned performance indicators. Experimental research lasted 28 days and was conducted in a recirculating aquaculture system. Two experimental rearing variants were utilized to evaluate compensatory growth: variant V1, the control variant (initial stocking density - 4.545 kg/m³, number of carp fish- 40), where fish were fed continuously for 28 days, while in V2 (initial stocking density - 4.485 kg/m³, number of carp fish- 40) the fish were starved for 3 days and then refed for 4 days, also for 28 days. The most significant technological indicators of crop biomass are as follows: the feed conversion factor recorded values of 1.18 g feed/g biomass spore in V1 and 1.25 g feed/g biomass spore in V2; the specific growth rate showed values of 1.735 %/day in the control variant and 1.67 %/day in the variant where the biological material was starved and then refed. The analysis of growth dynamics in the crop biomass highlights the potential of juvenile carp to recover the weight lost during the starvation period, reaching approximately the same biomass as in the control variant.

**Keywords**: carp, compensatory growth, recirculating system.

## 1. Introduction

Compensatory growth is a term used to describe a period of increased feeding, usually following a short period of starvation. The literature emphasizes that a species whose growth has been stunted by nutrient deprivation may exhibit an increased growth rate when feeding is resumed, obviously at an increased intensity [1]. The compensatory growth capacity of a fish species depends on a multitude of factors among which the most important are: technological plasticity, duration and severity of the starvation period, disease states, inadequate technological management [2], misjudgment of feed requirements, unpredictable changes in environmental conditions naturally accompanied by growth depression [3].

Authors such as Ali M. et al. (2003) [3] associate compensatory growth with a more active feeding behavior and an increase in appetite/hyperphagia. Other authors [4-6] explain compensatory growth by better utilization of food, i.e., a reduction in the proportion of uneaten food.

The possibility that compensatory rearing could completely recover the mass gain lost during the starvation period could be a judicious technological opportunity to achieve the planned performance indicators [7, 8], i.e., a way to increase the profitability of aquaculture [9, 10].

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## 2. Materials and methods

The experimental research was carried out in a recirculating system consisting of 4 aquarium-type rearing units with a useful volume of 300 L and dimensions of 100×80×40 cm.
The recirculating system used was designed in such a way that it was possible to control and maintain the main physico-chemical parameters of the water, namely: oxygen content, nitrogen compounds, temperature, and pH, within the optimum range.
From a construction point of view, the recirculating system (Figure 1) consists of the following component parts: rearing units; water quality conditioning units, consisting of: mechanical water filtration unit, biological water filtration unit, water sterilization unit (Tetra Quiet UV-C 35000, 36 W), water aeration-oxygenation unit; water distribution to the growth module.

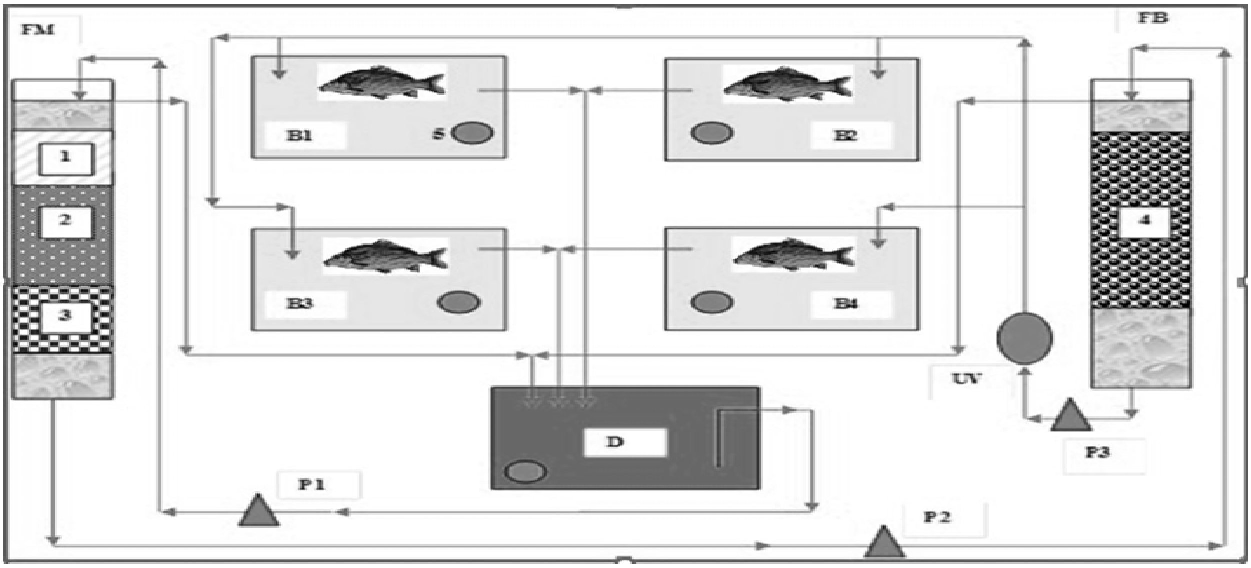


**Figure 1**. Recirculating system scheme
(B1-B4)- aquariums, D-decanter, (P1-P3)-pumps, UV-sterilization lamp, FM-mechanical filter, FB-biological filter, 1-burette, 2-sand, 3-pietrips, 4-bactobols

The experiment lasted 28 days. The biological material used in the present experiment was 5-month-old carp *(Cyprinus carpio*, Linnaeus 1758) fry, obtained at the Experimental Laboratory of the Research and Development Institute for Aquatic Ecology, Fisheries and Aquaculture, Galati.
To evaluate the compensatory growth of juvenile carp in a recirculating aquaculture system, V1 (B1, B2) were fed continuously for 28 days while V2 (B3, B4) were starved for 3 days and then fed for 4 days; this cycle was also repeated for 28 days. At the end of the experiment, the quantity of feed distributed per tank was the same in both experimental variants, 1001 g of CLASSIC EXTRA 1P type feed, suitable for juvenile carp, both in terms of protein content (41%) and granulation size (2.5 mm). The protein content of the feed plays an important role in obtaining the planned culture biomass [11, 12]. In the V1 variant the total amount of forage (2.5% of the biomass) was divided and distributed equally on each day ($9^{00}$, $12^{00}$, $15^{00}$, $18^{00}$ hours), while in the second variant, in which the young carp were starved and refed, the total amount was divided over the 16 days of refeeding. In the present experiment, all fish in the four rearing units (20 fish/rearing unit) were measured and weighed at the beginning and the end of the experiment, determining total length (L±1mm) and body mass (W±1g). The main bioproductive parameters were calculated from the measurements.
The experimental data were statistically processed, and the following statistical test was used: the parametric t-Student test (comparisons between means, significance $p < 0.05$).

## 3. Results and discussion

Weight recovery in fish can be influenced by some environmental factors such as water

temperature, water quality (oxygen, ammonium, nitrate, nitrite content), and season [1, 5].
Knowing this, a basic concern in the organization of the experiment was to keep the water quality parameters within the optimal technological range by a rigorous control of the operation of all treatment stages in the recirculating system configuration.
The specialized literature recommends, for compensatory rearing, the use of batches of fish as homogeneous as possible and the use of duplicate experimental variants so that the results obtained can be considered reliable [3]. Thus, the mean initial weights were approximately equal in all rearing units except the average mass in B2, which was higher both at the beginning and at the end of the experiment (Figure 2). It is worth noting that the variability of the experimental batch is more pronounced in the case of continuously fed carp broodstock compared to starved and refed biological material.

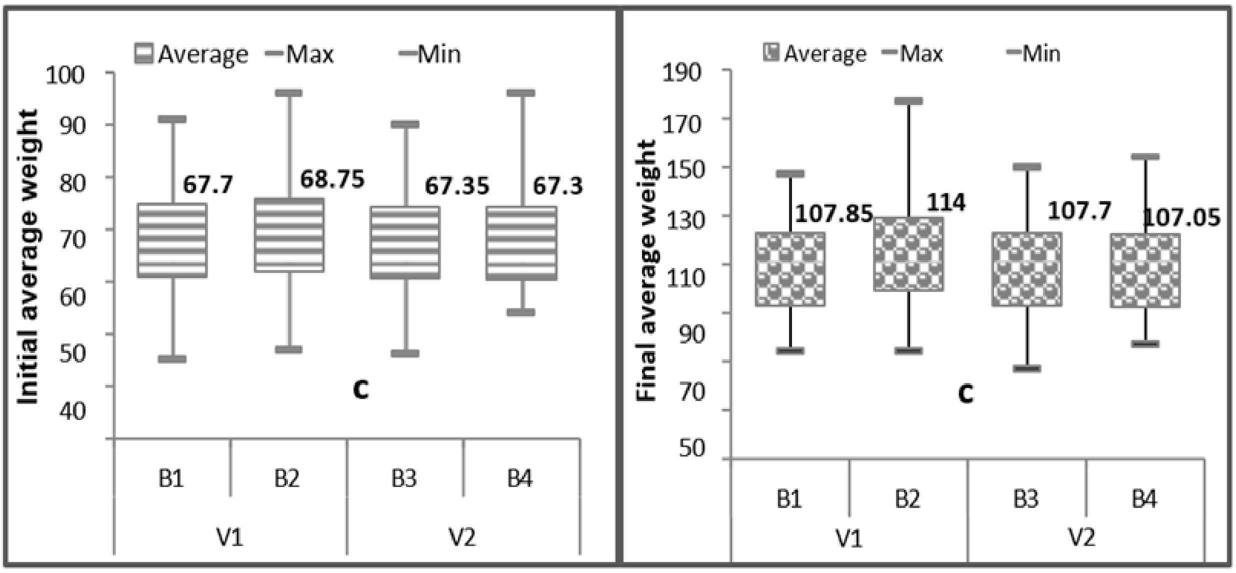


**Figure 2.** Initial and final masses - mean, minimum, and maximum values
c - "insignificant differences between the weights of the specimens of the two variants"
d-"significant differences between the weights of the specimens of the two variants"

From the analysis of the growth equations, presented in graphical form (Figures 3 and 4) for each of the experimental variants, the following observation emerges: the value of the parameter $R^2$ shows a decrease in the homogeneity of the condition coefficient in the variant in which the specimens were fed continuously and an increase in the homogeneity of the condition coefficient in the variant in which the specimens were starved and refed. Statistical testing of the weights and lengths of juvenile carp in the two variants revealed no significant differences for the 95% confidence threshold at the start of the experiment (p>0.05, p= 0.37 for the mass of the fish, p= 0.32 for the length of the juvenile). Statistical testing of the weights and lengths at the end of the experiment revealed the following.
While no statistically significant differences were observed between the weights of juvenile carp in both experimental variants (control, starved and refed, respectively) at the end of the experiment (p = 0.24, p > 0.05;), significant differences were observed in the lengths of juvenile carp (p = 0.02, p < 0.05). We can thus see that the biological material showed a total compensatory increase in mass and a partial compensatory increase in length at the end of the experiment. The data obtained are comparable with those in the literature, which also describe a partial compensatory increase in length [9]. The dynamics of crop biomass growth in the two variants are also evidenced by the established parameters of growth performance presented/reported in Table 1.

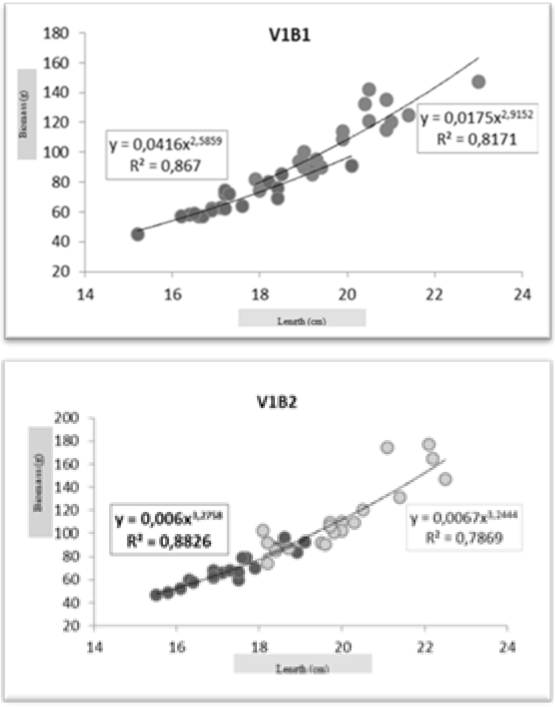


**Figure 3.** Length-weight regression for V1 fish groups at the beginning and end of the experiment

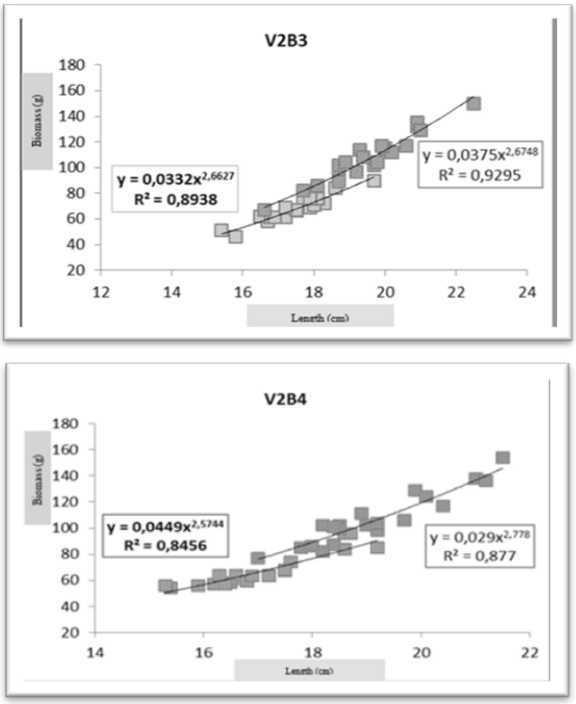


**Figure 4.** Length-weight regression for V2 fish groups at the beginning and end of the experiment

**Table 1.** Technological indicators of carp farming

| Experimental variant | Unit of measurement | V1 | | V2 | |
|---|---|---|---|---|---|
| **Indicator/basin** | | **B1** | **B2** | **B3** | **B4** |
| **Initial biomass** | **(g)** | **1354** | **1375** | **1347** | **1346** |
| Initial storage density | (kg/m³) | 4,51 | 4,58 | 4,49 | 4,48 |
| **Final biomass** | **(g)** | **2157** | **2280** | **2154** | **2141** |
| Final storage density | (kg/m³ | 7,18 | 7,59 | 7,17 | 7,13 |
| **Biomass growth** | **(g)** | **803** | **905** | **807** | **795** |
| **Biomass growth gain** | **(kg/m³)** | 2,67 | 3,01 | 2,69 | 2,65 |
| Initial number of fish | - | 20 | 20 | 20 | 20 |
| Final number of fish | - | 20 | 20 | 20 | 20 |
| Survival | (%) | 100 | 100 | 100 | 100 |
| Initial average weight | (g/eg) | 67,70 | 68,75 | 67,35 | 67,30 |
| Final average weight | (g/eg) | 107,85 | 114,00 | 107,70 | 107,05 |
| Growing days | days | 28,00 | 28,00 | 28,00 | 28,00 |
| **Daily growth rate (GR)** | **(g/day)** | 28,68 | 32,32 | 28,82 | 28,39 |
| **Specific growth rate (SGR)** | **(%/day)** | **1,66** | **1,81** | **1,68** | **1,66** |
| Individual growth gain | (g/ex.) | 40,15 | 45,25 | 40,35 | 39,75 |
| Total mount of feed administered | (g) | 1001 | 1001 | 1001 | 1001 |
| **Feed conversion ratio (FCR)** | **(g feed/g gain biomass)** | **1,25** | **1,11** | **1,24** | **1,26** |
| **Protein efficiency ratio (PER)** | **(g/g protein)** | **1,95** | **2,20** | **1,96** | **1,93** |
| Daily biomass | (%biomass) | 2,5 | 2,5 | 2,5 | 2,5 |
| Crud protein feed (PB) | (%) | 41 | 41 | 41 | 41 |

The analysis of crop biomass dynamics shows the potential of the starved and refed variant to recover the weight lost during the starvation period to approximately the same biomass as the control variant (Figure 5).

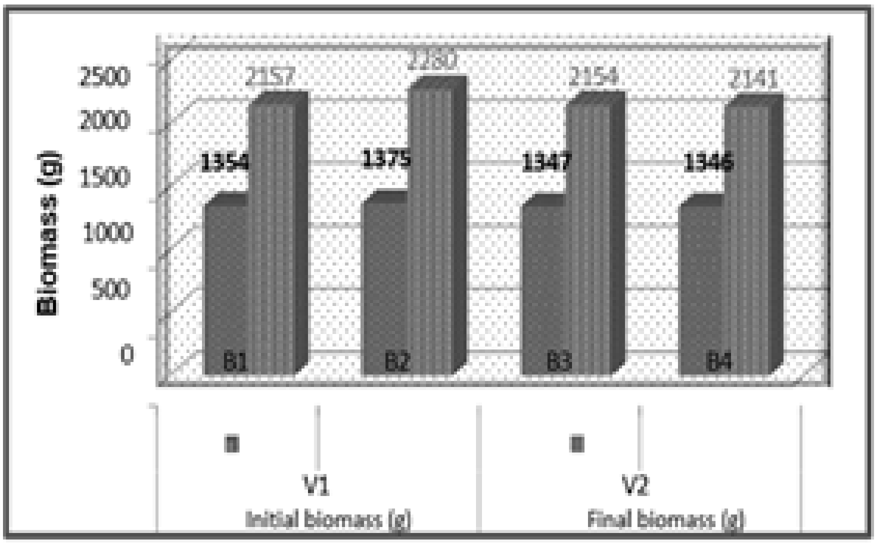


**Figure 5**. Biomass evolution in the two variants

Specific growth rate (SGR) and feed conversion ratio (FCR) are parameters that faithfully express the dynamics of individual growth and/or crop biomass in the two experimental variants. Thus, the feed conversion ratio (Figure 6), calculated as the average of the two replicates, recorded a value of 1.18 g feed/g biomass in the continuously fed variant and 1.25 g feed/g biomass in the starved and refed variant.

The feed conversion factor values are essentially equal in the two variants, suggesting that the 3-day starvation did not affect the forage conversion capacity of the fish, and that they were able to regain the lost weight on the days of refeeding by similar forage conversion, as observed in *Oreochromis mossambicus* under a similar compensatory rearing protocol [13]. The specific growth rate (SGR), inversely proportional to the feed conversion ratio (FCR), also showed close average values for the two control variants: 1.735 %/day in the control variant and 1.67 %/day in the starved and refed variant.

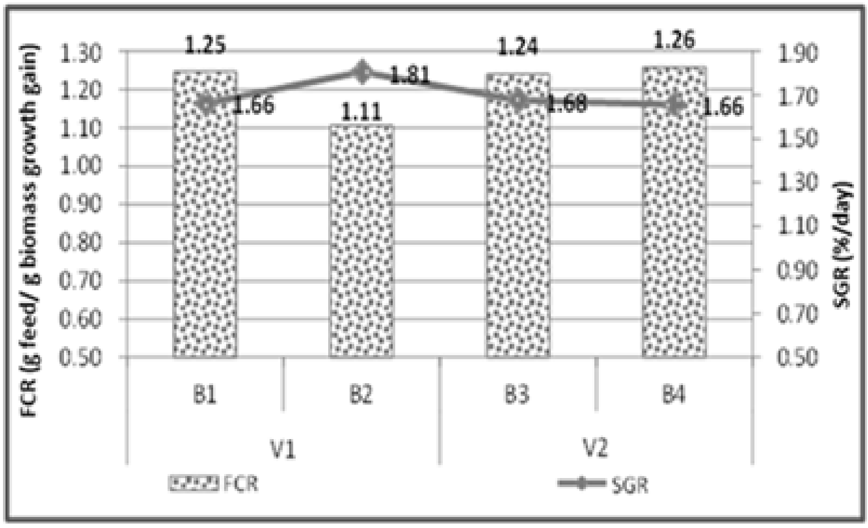


**Figure 6.** Feed conversion ratio (FCR) and specific growth rate (SGR)

By using a similar protocol (2 days starvation and 5 days refeeding, respectively 2 days starvation and 2 days refeeding) to that used in the present experiment, Känkänen M. [14] obtained comparable results for *Coregonus lavaretus*. Thus, the specific growth rate and feed conversion factor recorded in the control variant are higher, as in the present experiment, but with no statistically significant differences compared with the starved variant.

In contrast, by using a protocol in which the number of days that fish are starved is greater than the number of days that fish are refed, total compensatory growth is no longer possible for *Sander lucioperca* [15], *Oreochromis mossambicus* [16] and *Ctenopharyngodon idella* [17].
The protein conversion factor (PER) is an indicator directly dependent on the growth rate and the amount of protein in the ingested feed. For this reason, the PER varied in direct proportion to the specific growth rate (SGR), the values of these two parameters being higher in the variant where the young carp were fed continuously; the graphical representation of the two parameters is shown in Figure 7.

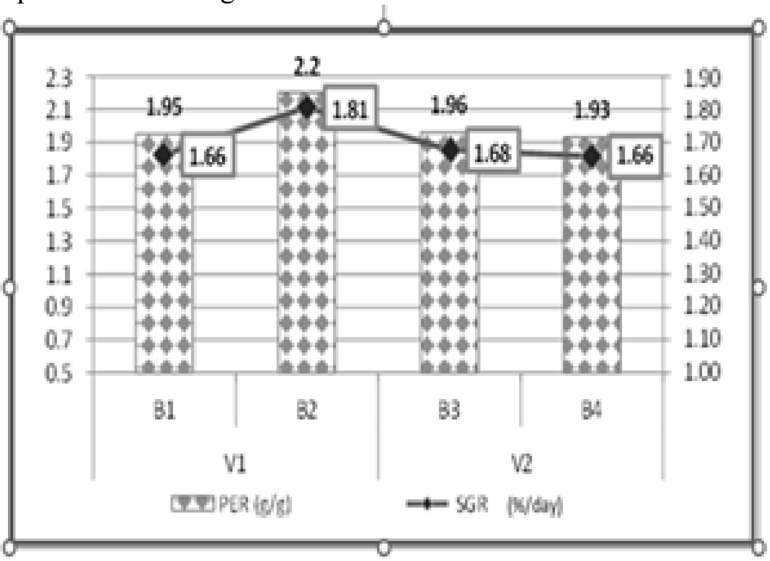


**Figure 7.** Protein conversion ratio (PER) and specific growth rate (SGR)

A lot of research has been carried out to elucidate the complex mechanism of the compensatory growth process, obviously focused on the main culture species: salmonids [ 1, 3, 4] and cyprinids [18-22]. An overcompensation, the ideal case of compensatory growth, was reported for the species *Lepomis cyanellus*×*Lepomis macrochirus* [23], a limited capacity for compensatory growth was reported for tilapia *Oreochromis mossambicus ×Oreochromis niloticus* [24], tench *Tinca tinca* [22] and gilthead seabream *Sparus aurata* [25]; no compensatory growth response was observed in common carp *Cyprinus carpio* [3].
In contrast to these results, the values of all the performance indicators, together with the statistical calculation applied, highlight, in the present experiment, the potential of *Cyprinus carpio* to show an almost total compensatory weight gain at the end of the experimental period.

## 4. Conclusions

The objective of the present study was to evaluate the compensatory growth potential of carp, a particularly complex process. From the critical analysis and statistical processing of the growth performance indicators obtained in the two experimental variants, a rather important conclusion regarding the assumed hypothesis, namely, the compensatory growth potential of juvenile carp under a recirculating aquaculture system, is drawn.
Recognizing that weight recovery can be affected by water quality parameters, a main objective of the experiment was to maintain the physico-chemical parameters of the water within the optimal range of the species and without differences in the values of these parameters in the two variants, which could be achieved due to the functionality of all water treatment steps/equipment.
Even though the experiment was a short-term study (28 days), the values of all performance indicators, together with the statistical calculation applied, highlight in the present experiment the ability of *Cyprinus carpio* to show a total compensatory increase in mass after a relatively

short period of starvation, providing a basis for future studies.

Although, there are no intermittent feeding practices used by fish farmers, and the use of certain restriction/feeding protocols could save the fish farmer work and food, we can conclude based on all the results obtained, that *Cyprinus carpio* species presents a remarkable technological plasticity, managing to fully recover the weight lost during the starvation period, the species being a viable alternative for diversification of culture species and production systems in Romanian aquaculture.

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