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Impact of Rationing on Growth Parameters (Length-weight) and Survival of *Sarotherodon melanotheron* Rüppell, 1852 Larvae at the Layo Aquaculture Experimental Station in Ivory Coast

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Authors' contributions

This work was carried out in collaboration among all authors. Authors KMN and YLA designed the study and wrote the protocol. Authors KMN, YLA and BACA conducted the experiment. Authors KT and AJPA carried out statistical analysis of the data. Authors KMN and AJPA wrote the first draft of the manuscript. Author KY supervised the work. All authors read and approved the final manuscript.

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ABSTRACT

Fish feeding is one of the major constraints to the development of fish farming. The general objective of this work is to contribute to the improvement of aquaculture production. Specifically, it involves determining the physicochemical parameters of the breeding water ; larvae growth parameters and the survival rate of *Sarotherodon melanotheron* Fry. To this end, three batches (1, 2, 3) of 75 individuals, tested in triplicate, were formed in 50 L happas. For 5 weeks, they were fed with Koudijs feed at ration rates of 10% (batch 1), 20% (batch 2) and 30% (batch 3) of biomass. Each week, physico-chemical parameters were recorded, and 10 Fry were taken at random from each happa, weighed and measured individually. At the end of the experiment, all surviving individuals per batch were counted. Results showed that the temperature (28.98 ± 1.21°C), the dissolved oxygen (6.826 ± 0.92 mg/l) and the pH (6.946 ± 0.77) were within the range recommended for rearing this species. Zootechnical parameters such as Average Weight, Average Size, ADG and Survival Rate of individuals from batch 2 (20%) were better, with respective values of 1745 ± 297.71 mg; 45 ± 2.5 mm; 49.01 ± 2.91 mg/d and 100%. However, the lowest values for Average Weight (1574 ± 381.57 mg), Average Size (43.6 ± 3.31 mm) and ADG (44.11 ± 1.70 mg/d) were recorded in batch 1. In view of the results, fish farmers should opt for the 20% rationing rate.

Keywords: Rationing rate; fry; happas.

1. INTRODUCTION

Aquaculture plays an increasingly important role in global fish production (Hilborn et al., 2018). Global aquaculture production reached 122.6 million tonnes in 2020, an increase of 6.7 million tonnes compared to 2018 (FAO, 2022). Production has increased in all regions, with the exception of Africa. However, per capita fish consumption in Africa is among the highest in the world, with over 20 kg/capita/year (Abdoullahi et al., 2018).

In Côte d'Ivoire, fish is the main source of animal proteins in the population's diet (COMHAFAT, 2014). Despite its 550 km long coastline, national fish production (fishing and fish farming) remains unfortunately limited and is unable to cover national needs (MIRAH, 2022). It covers only 17% of the population's needs, and the shortfall is made up by fish imports (MIRAH, 2019). According to Yayo et al., (2020) national fish production was 116,028 tonnes, compared with a requirement of over 618,182 tonnes, which was met by 549,233 tonnes of frozen fish imports. To reduce these imports, which generate considerable foreign currency outflows, the Ivorian government has made the aquaculture sector a priority in its development policy (COMHAFAT, 2014). It has set up mechanisms to promote fish farming. In order to achieve fish self-sufficiency, structures such as the Oceanology Recherches Center (ORC) have been set up to help improve breeding techniques, optimize production systems and develop new varieties of fish adapted to local conditions. Among these species, the tilapia *Sarotherodon melanotheron* has attracted a great deal of interest due to the quality of its flesh, its ability to reproduce at any time of year and its rearing in lagoons and fresh waters (Dankwa et al., 2016).

In addition, several research studies (Alla et al., 2011; Atsé et al., 2012; N'dri et al., 2016; N'dri et al., 2021) have shown that one of the difficulties in fish farming is the availability of feed. Little is known about research into the appropriate rationing rate for the *S. melanotheron* species in happas. For this reason, this study was initiated to contribute to the improvement of rearing techniques for this species. Specifically, the aim is to determine the physico-chemical parameters of the rearing water and the zootechnical parameters of this species reared in happas.

2. MATERIALS AND METHODS

2.1 Study Area

The present study took place at the Layo Experimental Aquaculture Station (Fig. 1), over a two-month period (from April 12 to June 10, 2024). This ORC research station is located 40 km from Abidjan, on the Abidjan-Dabou road.

2.2 Biological Material

The animal biological material consisted of *Sarotherodon melanotheron* Fry with a average weight of 30 ± 7.39 mg and a average total length of 12.63 ± 0.57 mm (Fig. 2A). The fish were harvested from a concrete production tank at the Layo Experimental Aquaculture Station.

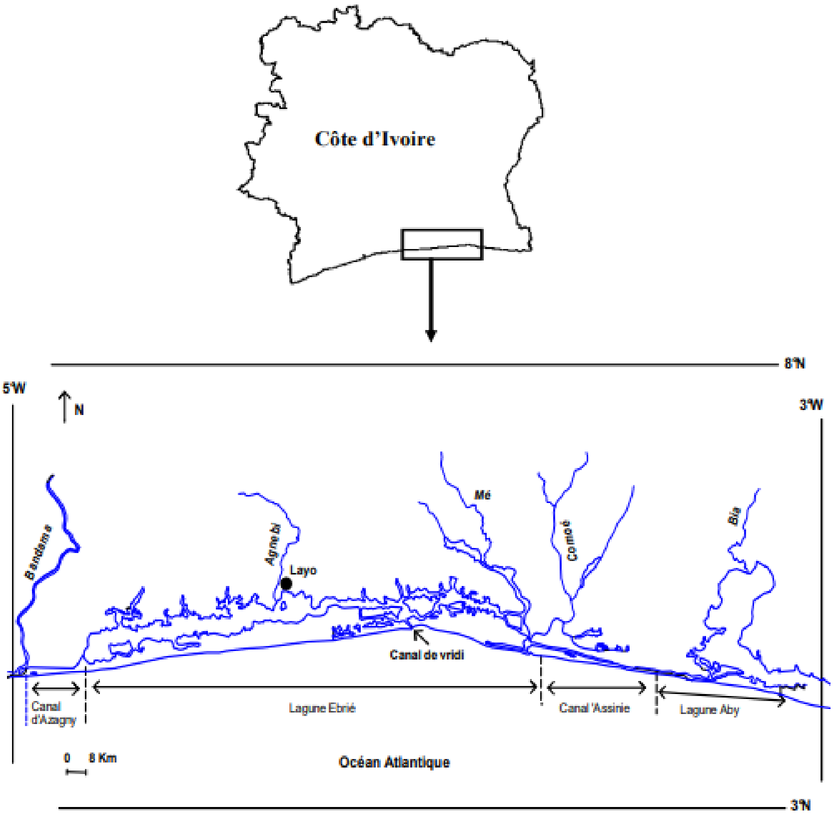

Fig. 1. Geographical location of the Ebrié lagoon and location of the Stationof Layo Experimental Aquaculture (Sylla et al., 2009)

The fish were fed with a commercial "Koudijs Tilapia Starter 2.0 mm" feed containing 35% crude protein, 5.5% crude fat, 5.0% crude fiber, 11.0% moisture and 14.0% ash (Fig. 2B).

2.3 Technical Equipment

The technical equipment consisted of the following items :

- a Fisher Scientific precision balance with digital display, with a precision of 0.01g, for weighing Fry during sampling and feeding distributed ;
- a ruler graduated in millimetres, 30 cm long, to measure the size of the fish ;
- an electric mixer model LX-313 (220/50Hs 350W) to crush the food under a vacuum. granulated form before feeding;
- landing nets with mosquito netting handles to catch Fry during sampling;
- a multi-parameter for measuring the water's physico-chemical parameters;
- brushes for cleaning happas.

2.4 Experimental Set-up

To carry out this experiment, nine happas of identical volume were installed in a pond. They were constructed from fine mesh (1.5 mm) and arranged in three rows of three happas (Fig. 3). Each happa, with an average volume of 50 liters, was supported by four Chinese bamboo stakes of varying lengths and driven firmly into the pond sediment. To facilitate data collection, the happas were labelled according to ration rates.

Before batches were formed, 30 Fry were collected, weighed and measured individually using the precision balance and graduated ruler, to determine average weight and average starting length. Following this stage, 225 *S. melanotheron* Fry were selected and divided into three batches of 75 individuals. The batches were :

- Batch 1: submitted to the 10% biomass rationing rate;
- Batch 2: submitted to 20% biomass rationing;
- Batch 3: submitted to 30% biomass rationing.

Fig. 2A. Fry of *S. melanotheron*

Fig. 2B. Koudijs tilapia feed

Fig. 2. Biological material used during the experiment

Fig. 3. Experimental Happas in ponds

Each batch was tested in triplicate at a density of 0.5 individuals/L of water.

2.5 Experimental follow-up

2.5.1 Feeding

Before the fish were fed, the Koudijs feed, in granulated form and not adapted to the size of the subjects, was crushed using the LX-313 electric mixer to adapt it to the size of their mouths. The daily rations (DR) distributed per day depended on the rationing rate assigned to each batch. They were calculated using the following formula : DR = Average weight x Ration rate x Number of individuals. This calculation was used to adjust the daily ration after each sampling. The fish were fed manually, at the same frequency of three rations per day (7am, 11am and 3pm).

2.5.2 Measurement of physico-chemical parameters

The physico-chemical parameters (Temperature, pH and Dissolved Oxygen) were read each week before the first feed using the multi-parameter. The procedure consisted in immersing the device's probe directly in the water, then switching it on. After stabilization, the readings were recorded in a notebook.

2.5.3 happas maintenance

The condition of the happas was checked every morning before the first meal of the day. Those with holes or tears were patched. Happas were cleaned on a weekly basis to remove feces, uneaten food scraps and mud from the mesh.

2.5.4 Sampling

Samples were taken every week to monitor fish growth. Ten Fry were taken at random from each happa, weighed and measured individually, using a precision balance and a transparent 30 cm ruler graduated in millimetres. At the end of the experiment, all surviving individuals per batch were counted.

2.6 Calculated Zootechnical Parameters

Average weight of juveniles (AW) : It is determined by the ratio of the sum of the weights of the individuals in the same batch to their number, according to the following formula :

AW (g) = Sum of weights of individuals weighed / Total number of subjects weighed

Average juvenile length (AL):

It is determined by dividing the sum of the lengths of individuals in the same batch by their number, using the following formula :

AL (cm) = Sum of lengths of individuals measured / Total number of subjects measured

Average daily gain (ADG):

ADG (g/d) = (Faw - Iaw) / t,

Faw: final average weight (g), Iaw: initial average weight (g) and t: rearing time (d).

Coefficient of Variation (CV):

It is used to check the weight and size uniformity of juveniles.

CV (%) = (100 x Standard deviation) / Average weight

Condition factor (K):

It reflects the overweight of poisons and is determined by the following formula :

K = (100 x Tw) / Tl^3 ; Tw = total weight of fish (g) and Tl = total length of fish (cm).

Survival rate (SR):

It is calculated as the ratio of the final number of fish to the initial number.

SR (%) = 100 x Fn / In where In : initial number of fish at loading and Fn : final number of fish.

2.7 Statistical Analysis

The data collected was processed using a computerized tool. Results were expressed as average ± standard deviation. Excel version 2016 was used to enter and organize the data, and to produce the graphs. Some results were subjected to a one-way analysis of variance (ANOVA) using STATISTICA 7.1 software. The significance threshold was 5%. The result obtained was significant if weight is less than 0.05 and non-significant if weight is greater than 0.05.

3. RESULTS

3.1 Physico-chemical Parameters of the Breeding Pond

Temperatures ranged from 28 to 31.1°C, with an average of 28.98 ± 1.21°C. The peak was recorded in week 2, followed by a slight drop in subsequent weeks. Temperatures remained relatively stable between weeks 3 and 5.

For dissolved oxygen, the lowest value (5.73 mg/l) was observed in week 4, while the highest value (8.3 mg/l) was recorded in week 1, with an average of 6.826 ± 0.92 mg/l.

The pH values obtained fluctuated between 5.73 (week 4) and 7.65 (week 1). The average determined was 6.946 ± 0.77.

3.2 Zootechnical Parameters

3.2.1 Growth by weight

Weight growth (Fig. 4) was ascending for all batches, from the beginning to the end of the experiment. From 30 ± 7.39 mg at the start of the experiment, average weights reached 1574 ± 381.57 mg ; 1745 ± 297.71 mg ; 1712 ± 250.71 mg for the 10%, 20% and 30% rations respectively. Weight growth was initially low during the first two weeks, followed by exponential growth from the third week onwards. Subjects fed with 20% and 30% rations achieved the best growth at the end of the experiment. Those in batch 1 grew significantly less (w<0.05) than those in the other batches.

3.2.2 Growth in length

The evolution of the average total length of the fish is illustrated in Fig. 5. The initial average lengths of the Fry increased from 12.63 ± 0.57 mm to 43.6 ± 3.31 mm in batch 1 ; to 45 ± 2.5 mm in batch 2 and to 44.73 ± 2.09 mm for individuals fed with 30% ration.

During the first two weeks, growth in length was almost identical for all rations, with a slight increase. From the third week onwards, the growth of fish fed with 10% ration remained slightly lower than those fed with 20% and 30% rations, until the end of the trial. However, the results were not significantly different (w>0.05) between batches.

3.2.3 Average daily gain (ADG)

In all batches, ADGs increased progressively until the end of the experiment to reach 80.23 ± 6.26 g/d ; 90.14 ± 5.76 g/d and 88.09 ± 8.04 g/d, respectively for batch 1, batch 2 and batch 3. However, over the entire five-week rearing period, batch 2 (20%) achieved the highest average daily gain, with an average of 49.01 ± 2.91 mg/d. This was followed by batch 3 (30%) with an average of 48.04 ± 1.43 mg/d. The 10% rationing rate showed a significantly lower average (w<0.05) than batches 2 and 3 (Table 1).

3.2.4 Consumption index (CI)

In this experiment, the CI values recorded varied according to the ration distributed. At the start of the experiment, they were relatively low, at 0.16 for the 10% ration, 0.32 for the 20% ration and 0.50 for the 30% ration. By the end of the study, the CIs had risen to 1.24, 2.47 and 3.69 for batch 1, batch 2 and batch 3 respectively. Over the entire trial period, the average CI was lower for the 10% ration (0.77 ± 0.39). The 30% ration provided the highest average (2.26 ± 1.16). Batch 2, on the other hand, recorded an intermediate value (Table 1). There was a significant difference (w<0.05) between the 3 batches.

3.2.5 Weight Coefficient of Variation (CV)

Coefficients of Variation of larvae weight ranged from 13.70 ± 7.72% to 24.61 ± 3.90%. At the 10% feeding rate, the calculated CV was 24.61 ± 3.9%. This seems to indicate higher variability compared with the 20% ration, which recorded a value of 16.17 ± 6.62%, and the 30% ration, which obtained the lowest CV (Table 1).

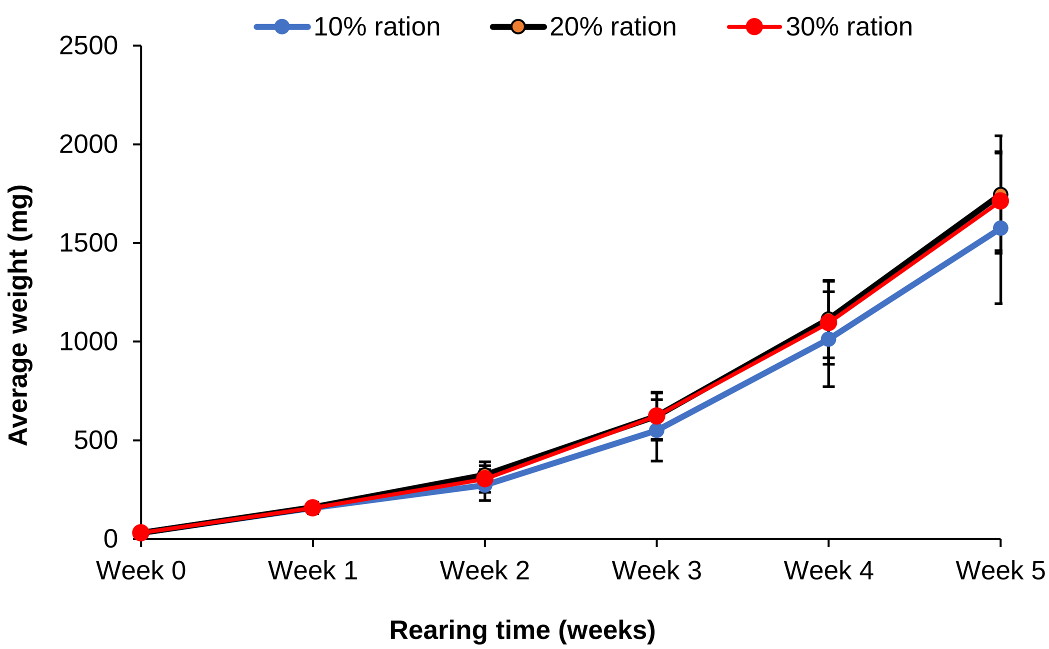

Fig. 4. Weight growth of *S. melanotheron* Fry as a function of rearing time

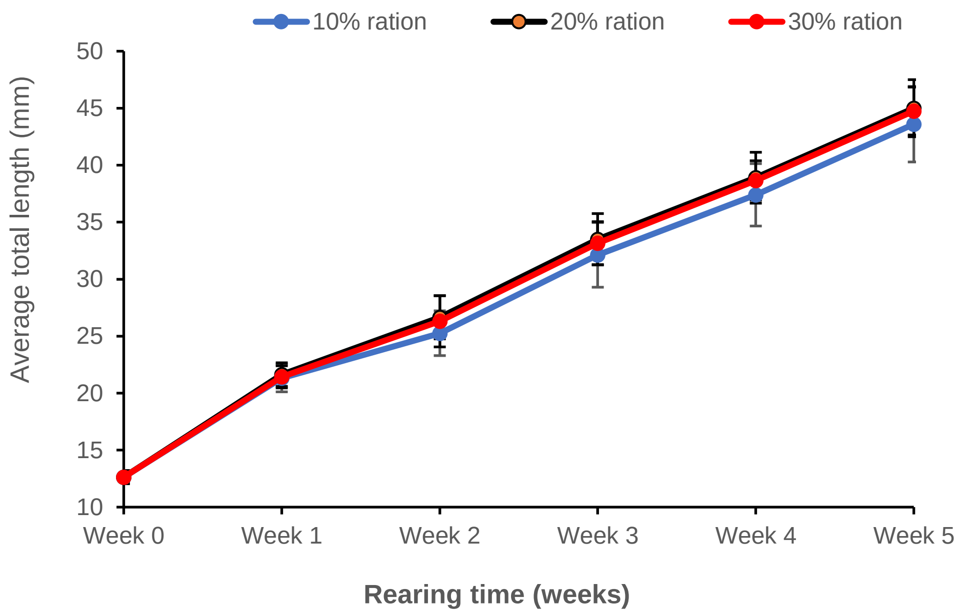

Fig. 5. Variations in *S. melanotheron* Fry size as a function of rearing time

Table 1. Variation in growth and survival parameters of *S. melanotheron* Fry as a function of rationing rate

Rations	ADG (mg/d)	CI	CV WEIGHT (%)	SR (%)
10%	44.11 ± 1.70^{a}	0.77 ± 0.39^{a}	24.61 ± 3.9^{a}	98.67^{a}
20%	49.01 ± 2.91^{b}	1.5 ± 0.78^{b}	16.17 ± 6.62^{b}	100^{a}
30%	48.04 ± 1.43^{b}	2.26 ± 1.16^{c}	13.70 ± 7.72^{c}	98.67^{a}

Values with the same alphabetical letters in the same column are not significantly different at the 0.05 threshold

3.2.6 Survival rate (SR)

At the end of the experiment, the survival rate was calculated for each happa. For all three rations tested, the survival rate was satisfactory. It ranged from 98.67% to 100% (Table 1). However, the highest survival rate was observed for the 20% ration. The 10% and 30% ration rates were identical and came last with a follow-up rate of 98.67% each. No significant differences were statistically observed between batches.

4. DISCUSSION

Physico-chemical water parameters (temperature, dissolved oxygen and pH) are important factors influencing fish survival and growth (Imorou Toko et al., 2013). In this study, the values recorded showed very little variation. The average temperature recorded was 28.98 ± 1.21°C. This was within the range 24.1 to 29°C ; 26 to 32°C and 27.2°C to 30.7°C obtained respectively by Diabagate et al., (2024), Campbell, (1987), Atsé et al., (2009). Dissolved oxygen levels averaged 6.82 ± 0.92 mg/l. According to Diabagate et al., (2023), dissolved oxygen levels above 3.5 mg/L are good dissolved oxygen levels in a rearing environment. Our results were compliant with those of Yapo et al., (2007) who recorded values of 5.2 to 8 mg/L. As for pH, it gave an average of 6.94 ± 0.77, which was within the range (6 - 9) recommended by Amoussou et al., (2016). According to Diabagate et al., (2023), the pH of the water at the Layo station varied from 6.1 to 8.3. On the other hand, our values were higher than those of Campbell, (1987) who observed that S. melanotheron grows and reproduces at a pH of 3.5 to 5.2. The values recorded for all physico-chemical parameters certainly favored larvae growth and health. In fact, they were in line with the standard values recommended for rearing this species. These results could be explained by the fact that the fish were reared in better conditions, due to good pond preparation, good happas maintenance and constant renewal of the pond water.

Overall, fish weight growth showed an upward trend for all three rations. This result could be justified by the fact that the fish were fed with a good-quality feed correlated with the positive effect of the rearing environment. However, during the first two weeks, the variation in average larvae weight was very small. This could be explained by the fact that, at this time, the fish were not yet accustomed to the feed and their new living environment (adaptation time). This observation is shared by Baras & Jobling, (2002), who have shown that periods of low initial growth are due to acclimatization. From week 3 to the end of the experiment, the fish progressively expressed their growth potential in weight and size. This could be explained by the fact that the fish took full advantage of the feed they were given. At the end of the trial, growth was better in larvae fed at 20% and 30% ration rates. These results could be justified by the fact that these rations had a direct positive effect on the growth of *S. melanotheron* larvae. However, the growth of fish in batches 2 and 3 was relatively confused. This may be linked to the fact that above a certain level of ration rate (20% in this case), further increases in ration lead to wastage without any proportional increase in growth. Our results corroborate those of Tacon & Metian, (2008), which showed that optimal rationing levels exist to maximize growth without wasting feed. Studies (Yao et al., 2016) have also noted that higher rationing rates can lead to poor nutrient use and increased metabolic waste, which could affect water quality, growth and larvae health.

With regard to ADG, the results showed a progressive increase in this parameter right up to the end of the experiment, with batch 2 larvae showing better growth (20%). This variation could be explained by physiological and behavioral adjustments of the larvae to changing feeding conditions, as well as by complex interactions between nutrition, metabolism and environment. Tilapia larvae show better growth and ADG with moderate feeding rates than with too low or too high rates (Santos et al., 2015; Shoko et al., 2016).

With regard to the feed conversion ratio, the values recorded varied according to ration. The lowest average CI was observed on the 10% ration (0.77 ± 0.39). This could be justified by the good transformation of the feed distributed. On the other hand, the most degraded CI was recorded at the 30% ration level, with an average of 2.26 ± 1.16. This result could be explained by the low feed conversion. Indeed, higher rationing rates can lead to an accumulation of undigested feed, reducing feed conversion efficiency. Increasing the rationing rate did not appear to improve feed conversion efficiency.

Coefficients of Variation in average larvae weight ranged from 2% to 30%. This means that growth was homogeneous, despite the different rationing rates. This population homogeneity could be linked to the fact that the larvae were well fed and showed a relatively stable response to varied feeding conditions.

Larvae survival rates ranged from 98.67% to 100%. These values were generally satisfactory. They were above the 80% described by Gangbé et al., (2022) as a good survival rate. These results are justified by the fact that the larvae were well fed and maintained in an adequate rearing environment. The low mortalities observed could be explained either by stress or by the handling of individuals during sampling.

5. CONCLUSION

All three rations tested had a positive effect on the growth and survival of *Sarotherodon melanotheron* Fry. However, individuals fed at the 20% and 30% ration rates showed the greatest growth in weight and length. Fry fed the 20% ration recorded the best values for ADG and survival rate. Growth was homogeneous in all batches. Looking ahead, it would be interesting to extend the duration of the experiment beyond five weeks to observe the long-term effects of rationing on the growth and health of the subjects.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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