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Effect of stocking density on the growth and survival of Tilapia juveniles (*Sarotherodon melanotheron*) reared in happas at Layo station (Dabou, Côte d'Ivoire)

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Abstract

A study was carried out to evaluate the effect of stocking density on the growth and survival of *Sarotherodon melanotheron* juveniles. To do this, 300 individuals with an initial average weight 4.13 ± 1.96 g and an initial average length 5.79 ± 0.89 cm were monitored for 42 days, in triplicate, at four densities (0.2; 0.4; 0.6 and 0.8 ind. /L) in happas of 50 liters volume. Fish were fed at 10% of their biomass with koudijs feed. A weekly sampling was carried out, during which ten (10) individuals were taken at random, they were weighed and measured individually. The physico-chemical parameters of water were measured daily. At the end of the experiment, the 0.8 ind. /L density gave the best growth results, with values of 16.27 ± 2.36g; 9.17 ± 0.92 cm; 0.29 ± 0.08 g/d ; 2.11 ± 0.08 and 443.67 ± 56.44 g, respectively for final average weight, final average length, ADG, condition factor and total biomass. For the survival rate, the highest value (95.00 ± 1.33%) was recorded in individuals with a density of 0.4 ind./L while those with a density of 0.8 ind./ L gave the lowest survival (80.00 ± 1.33%). Other densities could be tested and in other breeding structures to better appreciate the influence of this factor on the growth and survival of this species.

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Introduction

In Côte d'Ivoire, fish is the most accessible source of animal protein for all social classes, due to its availability in all seasons and its relatively lower price compared to meat (MIRAH, 2022a). Average annual consumption per capita is 25.6 kg (MIRAH, 2019). National fish production, estimated at around 100 000 tonne/year, remains insufficient regarding the needs of the population, estimated at over 600,000 tonne/year (MIRAH, 2022a). National aquaculture production is 4,500 tonnes per year, or 4.5% of national fish production. The annual deficit of almost 500,000 tonne/year is made up by imports in frozen form (Avit *et al.*, 2012; Ducroquet *et al.*, 2017). This represents a significant currency outflow of 310 billion CFA francs in the national budget (MIRAH, 2022a).

In order to raise the level of local production, the country has initiated several aquaculture and fisheries development programs, the latest of which are the PSDEPA (Strategic Plan of Livestock, Fishery and Aquaculture Development) (2014-2020), PSTACI (Strategic Program of Aquaculture Transformation in Côte d'Ivoire) and PONADEPA 2022-2026 (National Policy of Livestock, Fishery and Aquaculture Development). The aim is to reduce the country's dependence on the outside world and enable Ivorians to consume fresh local fish at a competitive price (MIRAH, 2022b).

Public organization including the Oceanological Research Center (ORC) were created and tasked with identifying and studying local species with aquaculture potential, in order to make them available to fish farmers (MIRAH, 2022a). Among the species, the Tilapia *Sarotherodon melanotheron* is a good candidate due to the quality of its flesh.

However, for successful intensive farming of this species, it is important to control stocking density, which remains a factor determining the productivity of fish farming systems. High stocking densities are a potential source of stress that can limit fish growth and well-being when physiological and spatial requirements are not met (Le Ruyet *et al.*, 2008). Fry from high-performance strains still fail to grow properly unless good stocking practices are followed (Osofero *et al.*, 2009). Stocking density is a major concern in fish farming. This is why, to contribute to the control of the breeding of tilapia *S. melanotheron*, we are undertaking the present study which has the theme "Effect of stocking density on the growth and survival of juveniles in happas".

The general objective of this work is to determine the optimal density which allows for better growth and survival results during the rearing of *S. melanotheron* juveniles.

Material and methods

Study area

The experiment took place at the experimental aquaculture station of Layo from April 30 to June 12, 2023, i.e. for 42 days. This site is located at the north bank of the Ebrié Lagoon, around 40 km west of Abidjan on the Abidjan-Dabou route.

Biological material

To constitute the different batches, 300 juveniles of *S. melanotheron* with an initial average weight of 4.13 ± 1.96 g and an initial average length of 5.79 ± 0.89 cm were used. These individuals (Fig. 1) were produced at the Layo station.

They were fed with a commercial feed called ''Koudijs'' (Fig. 2).

Technical equipment

It was composed of a digital precision balance from Fisher Scientific with a maximum capacity of 620 g and an accuracy of 0.001g, for weighing Fry during sampling; an OHAUS digital kitchen scale with a maximum capacity of 2000 g and an accuracy of 0.0 g, for weighing the daily ration; a 50 cm ichthyometer to measure fish size during sampling; a fishing seine (12 mm mesh, 35 m long and 9 m drop) to catch the fish from the ponds used to make up the experimental batches; two landing nets with 6 mm mesh handles for collecting juveniles during sampling; a HANNA multi-parameter for determining a number of physico-chemical parameters in the farming water and two brushes used to clean happas.

Farming infrastructures

For this experiment, 12 identical happas (Fig. 3) made of 1.5 mm and 50 liters of volume, were used. Each happa was 50 cm long, 40 cm wide and 40 cm deep. They were installed in four rows of three happas in a pre-prepared fish pond. Each row was supported by eight three-meter-long Chinese bamboo poles. The happas were suspended in the water on the bamboo at around 20 cm from sediment. The water depth in the happas was 25 cm, giving a useful water volume of 50 liters / happa.

Work methodology

Fish catching and packaging

Juveniles of *S. melanotheron* were caught in ponds using a 12 mm mesh seine. Those weighing between 2 and 5 g were selected and kept for two weeks in a cage previously installed in the experimental pond to enable them adapting to their new environment. They were fed as much as possible three times a day with a commercial ''Koudijs" feed.

Setting up experimental batches

Four batches of different stocking densities were created. Before allocating the fish to the batches, 30 individuals were sampled, weighed and measured individually to determine initial average weight and initial average length. Each density was tested in triplicate. The constituted densities were as follows:

batch 1 : 10 individuals, i.e. a density of 0.2 ind./L ;
batch 2 : 20 individuals, i.e. a density of 0.4 ind./L ;
batch 3 : 30 individuals, i.e. a density of 0.6 ind./L ;
batch 4 : 40 individuals, i.e. a density of 0.8 ind./L.

Breeding

Once the batches had been formed, the commercial feed ''Koudijs" with 35% of protein was used. Individuals were fed at 10% of their biomass with a daily ration distributed manually three times per day (7:30 a.m., 12:30 p.m. and 5:30 p.m.). A weekly sampling was carried out to monitor juvenile growth and survival. To do this, 10 individuals were taken at random from each happa, weighed and measured individually using a precision balance (Fisher Scientific brand) and an ichthyometer. After weighing, all the fish in each happa were counted to determine the biomass and readjust the weekly ration. At the end of the trial, all fish were weighed, measured individually and counted by batch.

Throughout the study period, some physico-chemical water parameter (Temperature, Dissolved oxygen content, pH) were measured in the pond every day at 7 a.m. prior to feeding. The probe of measuring device (a HANNA Multi-parameter) was immersed directly in the water, and the values of the parameters measured were displayed on the screen.

Zootechnical parameters evaluated

Average Daily Gain (ADG): It is calculated from the following relationship:

ADG (g/d) = (Final average weight – initial average weight) / Rearing period

Coefficient of variation (CV): It is determined by the following formula:

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

If CV less than 2%, the population is said to be very homogeneous;

If CV is between 2 and 30%, the population is said to be homogeneous ;

If CV is superior than 30%, the population is said to be heterogeneous.

Condition coefficient K : The condition factor K reflects the overweight of the poisons and is determined by:

$$K = \frac{W}{L^3} \times 100$$

Where P = total weight of fish in g and L = total length of fish in cm.

Survival Rate (SR): SR (%) = (Number of fish remaining / Initial number of fish) x 100

Total biomass: It represents the total mass of all remaining individuals per batch at the end of the experiment.

Data processing

The series of values obtained were first analyzed using descriptive statistics. To do this, certain data were represented graphically or tabulated to highlight certain trends. Statistical indicators such as the average and the standard deviation were also calculated. To compare averages between different batches, a one-way analysis of variance (ANOVA) was performed. If the hypothesis of equality was rejected, multiple comparisons of averages, with significant effects at $p < 5\%$, were carried out. In this case, Turkey's HSD test was used.

Results

Physico-chemical parameters of farming water

Temperatures ranged from 30.13 ± 0.13 to 30.40 ± 0.14°C with an average of 30.26 ± 0.19°C. Values recorded for dissolved oxygen ranged from 6 ± 0.12 and 6.3 ± 0.14 mg/L with an average of 6.20 ± 0.18 mg/L. Relative to pH, the values obtained were between 6.86 ± 0.41 and 7.07 ± 0.67 with an average of 6.97 ± 0.48.

Table 1. Average Daily Gain, Coefficient Variation of weight and length (CV) and Coefficient condition (K) of fish taking into account the density.

Experimental densities	ADG (g/d)	CV Weight (g)	CV Length (m)	K
Density 0.2 ind./L	0.22 ± 0.05	31.17 ± 16.07	11.23 ± 5.82	1.45 ± 0.75
Density 0.4 ind./L	0.26 ± 0.06	22.29 ± 7.28	7.47 ± 1.75	1.97 ± 0.02
Density 0.6 ind./L	0.26 ± 0.06	14.05 ± 5.11	6.77 ± 1.86	2.11 ± 0.08
Density 0.8 ind./L	0.29 ± 0.08	19.35 ± 2.85	7.17 ± 2.15	2.11 ± 0.08

Zootechnical performance

Weight growth

Fig. 4 shows the curves of variations in the average weight of juveniles as a function of time for each density.

From week 1 to week 2, densities of 0.2 ind./L ; 0.4 ind./L ; 0.6 ind./L and 0.8 ind./L gave relatively low growth (5.62±2.0 to 6.85 ± 2.59 g ; 6.00 ± 2.51 to 7.07 ± 2.72 g ; 7.13 ± 1.79 to 7.19 ± 1.71 g and 6.63 ± 2.11 to 7.77 ± 2.90 g).

Fig. 1. *Sarotherodon* b*melanotheron* Juveniles.

From week 2 to the end of the trial, weight growth was greater. The 0.8 ind./L density showed the best weight growth with 16.27 ± 2.36g against the lowest weight growth (13.43 ± 4.11 g) recorded with the 0,2 ind./L density. However, there was no significant difference between the different batches ($p > 0.05$).

Fig. 2. Feed used for fish feeding.

Length growth

The evolutionary curves of average fish size per density taking into account the duration of breeding are shown in Fig. 5.

Average juveniles size values were low from week 1 to week 2. Thus, their average total length increased from 6.41 ± 0.78 to 6.99 ± 0.89 cm for the 0.2 ind./L density, 6.49 ± 0.95 to 7.08 ± 0.91 cm for the 0.4 ind./L density, 6.78 ± 0.69 to 7.30 ± 0.81 for the 0,6 ind./L density and 6.78 ± 0.76 to 7.12 ± 0.86 cm for the 0.8 ind./L density. From week 2 to the end of the experiment, individuals of the 0.2 ind./L density had the lowest growth in length (8.70 ± 0.97 cm). However, the 0.8 ind./L density gave the highest length (9.17 ± 0.92 cm). The other densities 0.4 and 0.6 ind./L produced intermediate sizes of 9.15 ± 0.68 and 8.93 ± 0,60 cm respectively. No significant difference was observed between the sizes of juveniles at the different densities ($p > 0.05$).

Average Daily Gain (ADG)

The highest ADG value (0.48 ± 0.10 g/d) was observed in individuals with a density of 0.8 ind./L, at week 3. Conversely, the lowest value (0.01 ± 0.09 g/d) was obtained in the second week in individuals with a density of 0.6 ind./L.

Fig. 3. Happas used in the experiment.

Over the whole experimental period (Table 1), the highest ADG was also recorded in batch 4 (0.29 ± 0.08 g/d), followed by those from batches 2 and 3 The lowest value was observed at the 0.2 ind./L density with only 0.22 ± 0.05 g/d. however, these ADG showed no significant for all densities ($p > 0.05$).

Coefficient of variation for weight and length (CV)

CVs for average weight and average total length of fish from each batch are shown in Table 1.

In terms of average weight, Batch 1 produced a CV of over 30 %, while the CVs for the other 3 batches ranged from 2 to 30%. The limits of variation were 14.05 ± 5.11 and 31.17 ± 16.07% for 0.6 and 0.2 ind./L respectively. The CV of the density 0.2 ind./L is greater than 30% while that of the other three densities is between 2 and 30%.

Concerning the average total length, the coefficient of variation was 6.77 ± 1.86 and 11.23 ± 5.82% respectively for densities 0.6 and 0.2 ind./L. All CV values recorded were between 2 and 30%.

Condition coefficient (K)

The lowest value (1.45 ± 0.75) was recorded in individuals with a density of 0.2 ind./L. On the other hand, the highest value of the condition coefficient (2.11 ± 0.08%) was obtained in juveniles at densities 0.6 and 0.8 ind./L (Table 1).

Survival Rate

The highest survival rate was recorded in individuals from Batch 2 with proportion of 95.00 ± 1.33 %, while the lowest was observed in those from density 0.8 ind./L (80.00 ± 1.33 %). Values from density 0.2 ind./L and density 0.6 ind./L were 83.33 ± 0.44 % and 94.44 ± 1.11 % respectively.

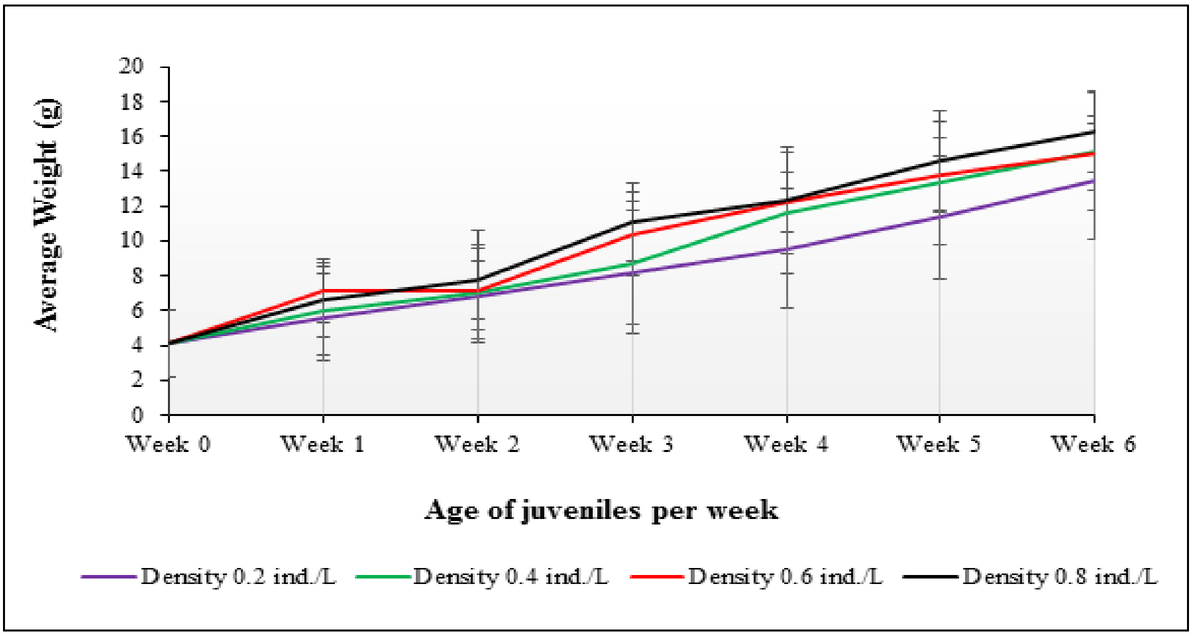

Fig. 4. Evolutionary curves of average weights per density taking into account the duration.

There is no significant difference between the survival rates calculated for the different densities ($p > 0.05$).

Total Biomass

The biomass increases with the loading density. Density 0.8 ind./L was at the top of the list with a value of 443.67 ±56.44 g, followed by density 0.6 ind./L and 0.4 ind./L with values of 332.00 ± 26.67 g and 228.00 ± 22.00 g respectively. The lowest total biomass was that of the 0.2 ind./L density (115.67 ± 1556 g).

There is a significant difference between the total biomass of the 0.2 ind./L density and the other densities (0.8; 0.6 et 0.4 ind./L). The same is true between the 0.4 ind./L density and the 0.8 ind./L density ($p < 0.05$).

Discussion

The different physicochemical parameters recorded in the happas during our experiment varied very little from one density to another. The averages of temperature, Dissolved Oxygen Rate and pH were 30.26 ± 0.19°C; 6.20 ± 0.18 mg/L; 6.97 ± 0.48, respectively. These values are within the range recommended by Jennings and Williams (1993) for temperature (17 °C and 32 °C) and by Ouattara *et al.* (2003) for pH (3.5 to 7.6). With regard to Dissolved Oxygen Rate, the average value obtained is higher than the critical value reported by Ross (2000) which is 2.3 mg/L for the *Sarotherodon melanotheron* species. The various physico-chemical parameters show that the fish increased under better rearing conditions. This may be justified by the fact that the water in the happas is permanently renewed.

With regard to the growth in weight and length of *S. melanotheron* juveniles, the curves show an upward trend, evolving in almost the same direction at all densities. This may be linked to the fact that the fish have benefited from a favorable environment and a good diet, enabling them to grow and develop. However, this growth is generally weak for each density during the first two weeks of rearing.

This situation could be considered as a period of adaptation of the fish to their new living environment. After the first two weeks, weight growth is the most important until the end of the experiment, with better growth in juveniles reared at density 0.8 ind./L.

This confirms the results of Amoussou *et al.* (2016) who assert that the growth of tilapia *Sarotherodon melanotheron* is discontinuous, characterized by a succession of periods of low and rapid growth.

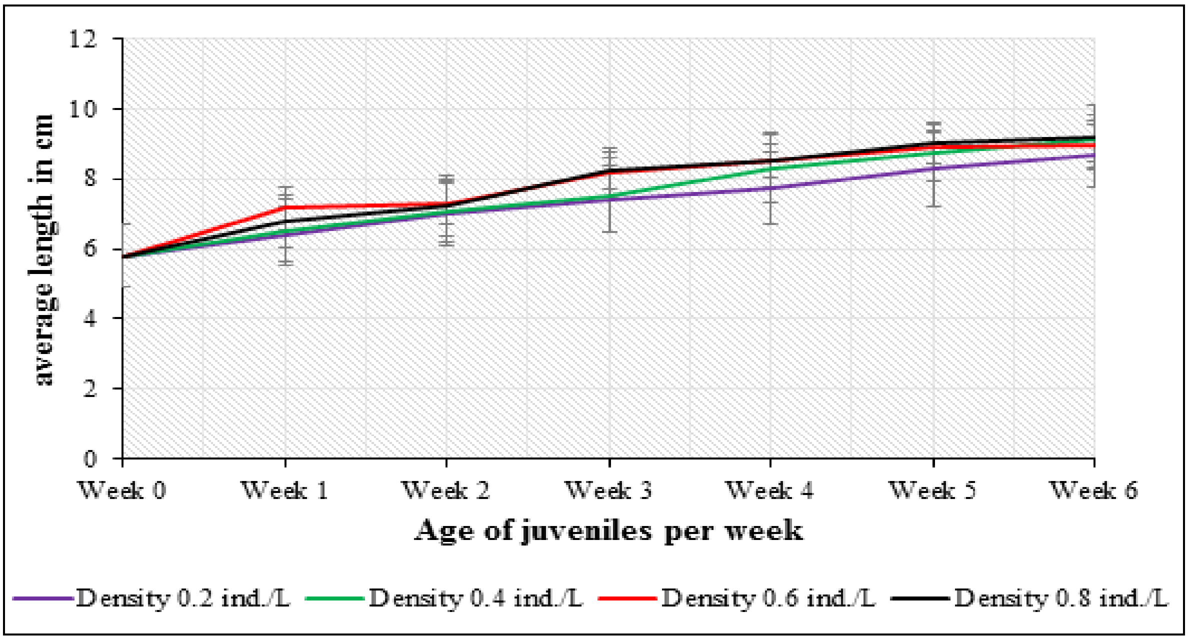

Fig. 5. Total growth of fish average length taking into account time and stocking density.

Over the entire testing period, the most important ADG was obtained for fish in Batch 4 (029 ± 0.08g/d). This value is lower than that recorded in the lagoon by Gbaï *et al.* (2014) for the same species (0.38 g/d). This difference could be explained by the structure of the food distributed during our study. In fact, the crushed feed contains a very few small grains that pass though the mesh of happas when the fish are agitated during the feeding.

CV values (weight and length) are ranged from 2 to 30 %, except for the CV of the 0.2 ind./L weight density (31.17 ± 16.07). This means that juvenile growth is relatively homogeneous for all densities. In addition, the overall condition coefficient K values are all above 1, justifying the overweight state of the fish. Our results are contrary to those of Avit *et al.* (2012) who worked on the tilapia *O. niloticus* in ponds associated with rice.

These authors obtained a condition coefficient lower than ours. However, the homogeneity of the different batches correlated with overweight condition could be explained by the fact that the densities tested and the feed distributed enabled the fish to be in optimal growth condition. Regarding juvenile survival rates, the lowest value was observed at density 0.8 ind./L (80.00 ± 1.33%). These results show that overall, survival was satisfactory and could be explained by the fact that the experiment was conducted in relatively good conditions. Our values are higher than those reported by Ouattara *et al.* (2005). Indeed, these authors obtained an average survival rate of 72.8 ± 3.9% in earthen ponds for the same species.

Our results indicate that the final total biomass increases with stocking density; which means that density has a positive effect on final biomass.

Conclusion

This study evaluated the effect of stocking density on the growth and survival of *Sarotherodon melanotheron* juveniles. The 0.8 ind./L density gave the best results for most of the zootechnical parameters studied. These include average weight, average length, ADG, condition coefficient and biomass, with values of 16.27 ± 2.36g; 9.17 ± 0.92 cm; 0.29 ± 0.08 g/d; 2.11 ± 0.08 and 443.67 ± 56.44 g respectively. In terms of survival rate, the 0.4 ind./L density recorded the highest proportion at 95.00 ± 1.33 %. Statistical analysis of the parameters studied showed that only the comparison between total biomass showed a significant difference at the level of the four (04) densities ($p< 0.05$). Looking ahead, it would be interesting to test other stocking densities and extend the experiment to grow up. Furthermore, we could conduct the experiment in other breeding structures. This would make it possible to better understand the effect of stocking density during the breeding of *S. melanotheron* in order to popularize it among fish farmers.

Conflict of interest

Les authors declare that they have no competing interests.

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