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Breeding Space as a Determinant of Growth Morphometrics, Gonadal Development, and Hepatic Condition in *Clarias gariepinus* (Burchell, 1822)

**Ekpo Inyang Paul¹, Ekpo Paul Bassey^{2,*}, Ekpenyong Bright Ntiero²
& Ozah Hosea Peter²**

¹ Department of Fisheries and Aquaculture, Faculty of Agriculture, University of Calabar, Calabar, Cross River State, Nigeria

² Department of Genetics and Biotechnology, Faculty of Biological Science, University of Calabar, Calabar, Cross River State, Nigeria

*E-mail address: Paulekpo988@gmail.com

ABSTRACT

This study investigated the impact of breeding space, specifically pond size, on growth, reproductive performance, and metabolic health in *Clarias gariepinus* (African sharptooth catfish), a species of significant aquaculture value. Ten fish samples sourced from ponds of varying sizes were assessed for morphometric parameters, including standard length (50.8 - 59.3 cm) and body weight (1400 - 2000 g), along with reproductive status measured by the Gonadosomatic Index (GSI: 0.2 - 5.0) and metabolic health assessed by the Hepatosomatic Index (HSI: 0.6-3.7). Fish reared in larger ponds showed significantly greater mean body length (58.9 cm) and body weight (1950 g) compared to those in smaller ponds (53.2 cm and 1450 g, respectively; $p < 0.05$). Similarly, liver weight and HSI values were higher in the large-pond group (HSI mean 3.4) relative to small-pond fish (HSI mean 1.2), indicating enhanced energy reserves. Correspondingly, GSI values were significantly elevated in larger ponds (mean 4.3) compared to smaller ponds (mean 1.1; $p < 0.05$), suggesting improved reproductive readiness. An inverse correlation ($r = -0.68$, $p < 0.01$) was observed between GSI and HSI, consistent with energy mobilization toward gonadal development during peak reproduction. Nevertheless, fish in optimal environments maintained relatively high levels of both indices, signifying the importance of adequate nutrition alongside space. These findings underscore pond size as a critical determinant of growth, reproduction, and metabolic condition in *C. gariepinus*. The study recommends that aquaculture practitioners prioritize larger, well-managed pond systems to optimize fish health and productivity. Regular monitoring of GSI and HSI is also advised to inform management decisions. Further research

is warranted to delineate the interactions between breeding space and environmental variables to refine sustainable practices, meeting global aquaculture demands while ensuring fish welfare.

Keywords: Breeding space, Gonadosomatic Index (GSI), Hepatosomatic Index (HSI), Aquaculture productivity, *Clarias gariepinus*

1. INTRODUCTION

Clarias gariepinus (Burchell, 1822), commonly known as the African sharptooth catfish, holds great significance in global aquaculture due to its rapid growth, environmental resilience, and strong market demand. As aquaculture expansion accelerates worldwide, optimizing production practices that enhance growth, health, and reproduction is critical (Ekpo *et al.*, 2023b). One key but often neglected factor is breeding space the physical area and stocking density provided to fish during cultivation. Adequate breeding space not only affects fish physiology and welfare but also determines overall production success.

Breeding space impacts water quality by influencing dissolved oxygen, ammonia levels, and metabolic stress. Overcrowding can degrade water conditions, limit growth, increase stress, and impair reproductive outcomes ((Ekpo *et al.*, 2023a; Ekpo *et al.*, 2018). In contrast, sufficient space improves metabolism, reduces competition, and promotes welfare, contributing to sustainable farming. Growth indicators such as body length, weight, and condition factor are vital metrics for assessing fish performance across different spatial conditions ((Ekpo *et al.*, 2018; Ekpo *et al.*, 2017). Complementing these, reproductive and metabolic health are measured using the gonadosomatic index (GSI) and hepatosomatic index (HSI). The GSI reflects the proportion of gonad weight to body weight, indicating reproductive status and fecundity, while the HSI gauges liver condition and energy reserves.

Despite the importance of these indices, there is limited direct research on how breeding space influences the morphometric, gonadosomatic, and hepatosomatic parameters of *C. gariepinus*. Addressing this gap is essential given the species' critical role in food security, especially in Africa where it ranks as the second most important freshwater aquaculture species after tilapia. Its hardy nature, air-breathing capacity, disease resistance, and prolific breeding make it ideal for captive farming in varied environments, including Asia and the Middle East.

Reproductive health measured by GSI is pivotal for sustaining fish populations and farm profitability, as it indicates reproductive maturity and readiness. Similarly, HSI signals the energy reserves necessary for growth and successful reproduction. Both indices are sensitive to environmental stressors such as limited breeding space and poor water quality. While studies have examined stocking density effects on growth and survival, fewer have investigated the specific influence of breeding space on these physiological indices in African catfish.

The justification for this research centers on balancing productivity improvements with ethical aquaculture practices. Overcrowded conditions diminish growth, elevate mortality and disease risk, and hamper reproduction, reducing economic returns (Ekpo *et al.*, 2022). Conversely, optimal breeding space enhances health and welfare, leading to more efficient and profitable production. Additionally, increasing consumer demand for sustainable and responsible aquaculture necessitates farming practices that align economic and ethical goals.

This study investigates the effects of breeding space on key morphometric and physiological parameters of *C. gariepinus*, including growth, reproduction (via GSI), metabolic

health (via HSI), and the relationship between space and water quality factors like oxygen and ammonia. By doing so, it aims to provide aquaculture managers and policymakers with evidence-based guidelines for fish welfare and productivity enhancement.

Research evidence indicates that breeding space significantly influences reproductive performance. Larger ponds generally yield higher GSI values, indicating enhanced gonadal development attributed to reduced crowding stress, better nutrient availability, and improved water quality. For instance, studies have shown that ponds larger than 500 to 1000 square meters promote greater reproductive success than smaller ponds due to lower stress and better environmental conditions. Conversely, some findings suggest that at smaller pond scales, feed quality and water parameters may have a stronger influence on GSI than space alone.

Mechanistically, increased breeding space reduces physiological stress, stabilizes water quality, and enhances feeding opportunities, fostering reproductive success. Larger environments also facilitate natural behaviors such as courtship and spawning by supporting natural food resources. Comparative studies across species like Nile tilapia reinforce that lower stocking densities and ample space correlate with improved fecundity and reproductive indices. Optimizing breeding space through adequate pond size, thoughtful design, and careful management is vital for maximizing the reproductive efficiency and sustainable seed production of *C. gariepinus* (Ekpo *et al.*, 2024; Ekpo *et al.*, 2023a).



Plate 1. Egg Sac of *Clarias gariepinus*.



Plate 2. Sperm Sac of *Clarias gariepinus*.



Plate 3. Liver of *Clarias gariepinus*.



Plate 4. Matured *Clarias gariepinus*.

This approach not only addresses biological needs but also serves economic and ethical imperatives in modern aquaculture. Understanding how breeding space affects growth, reproduction, and metabolism will guide the development of productive, environmentally responsible, and welfare-oriented aquaculture systems to meet the growing global demand for affordable fish.

Aim

The purpose of this study is to investigate how breeding space affects the morphometric, gonadosomatic, and hepatosomatic parameters of *Clarias gariepinus*. It aims to explore the impact of different space allocations on growth performance, reproductive status, and liver health, with the goal of generating data that can inform improved aquaculture practices for this species.

Objectives of the Study

- i) To evaluate the effects of varying breeding spaces on morphometric traits such as body length, body weight, and condition factor in *Clarias gariepinus*.
- ii) To examine how breeding space influences the gonadosomatic index (GSI), serving as a measure of reproductive health and capacity.
- iii) To assess the impact of breeding space on the hepatosomatic index (HSI), which reflects liver condition and overall metabolic health.

- iv) To investigate the relationship between breeding space and water quality variables, including dissolved oxygen and ammonia concentrations, to better understand environmental factors affecting fish health and growth.
- v) To develop evidence-based recommendations for optimal breeding space in *Clarias gariepinus* aquaculture systems to improve growth, reproductive success, and fish welfare.

2. METHODOLOGY

Collection and Location of Experimental Site

The fish samples were obtained from Bloorex Services Limited at 274 Old Odukpani Road, Ikot Ansa Qua Clan, Calabar, Cross River State, Nigeria, and transported to the Biology Laboratory of Lourdes Academy, Ekorinim, Calabar for analysis.

Materials

The study utilized *Clarias gariepinus* from a private farm, measuring tape, weighing balance, dissecting board, meter rule, record-keeping materials (book and paper), and gloves.

Methods

Morphometric Analysis

Morphometric measurements included Standard Length (SL), measured from the tip of the snout to the base of the caudal fin using a thread and meter rule. Body Weight (BW) was determined with a weighing balance. Fin lengths (caudal, pelvic, and pectoral) and body dimensions (body depth, body width, head length, and head width) were recorded using a thread and meter rule. The length of the genital papilla in males and cloaca width in females were also measured.

Gonadosomatic Analysis

The Gonadosomatic Index (GSI) was calculated by weighing the gonads on an electronic compact scale and the fish body on a weighing balance. GSI was determined using the formula:

$$\text{GSI} = (\text{Gonad weight} / \text{Body weight}) \times 100\%.$$

Hepatosomatic Parameters

The Hepatosomatic Index (HSI) was determined by weighing the liver with an electronic compact scale and the fish body on a weighing balance. HSI was calculated as:

$$\text{HSI} = (\text{Liver weight} / \text{Body weight}) \times 100\%.$$

Statistical Analysis

Descriptive statistics such as means, standard deviations, and ranges were calculated for morphometric parameters, GSI, and HSI. Inferential statistics included t-tests and ANOVA for mean comparisons, Pearson's correlation coefficient for correlation analysis, and linear

regression for assessing relationships. Multivariate analyses, including Principal Component Analysis (PCA) and Canonical Discriminant Analysis (CDA), were conducted to investigate differences in morphometric parameters, GSI, and HSI across breeding spaces.

3. RESULTS

Morphometric measurements

The standard length (SL) of the sampled *Clarias gariepinus* ranged from 50.8 cm to 59.3 cm. The highest standard length was recorded at 59.3 cm in sample 2, while the lowest was 50.8 cm in sample 6. The average standard length across all samples was approximately 54.2 cm. The data suggest that pond size may have influenced the standard length, with larger pond sizes potentially allowing for more space for the fish to grow. Fish with the highest standard lengths were primarily from larger pond environments, which may have contributed to their extended growth. Body weight (BW) among the samples varied from 1,400 g to 2,000 g. Samples 1 and 2 both recorded the highest body weight at 2,000 g, while samples 5 and 6 showed the lowest body weight at 1,400 g. The mean body weight across the ten samples was approximately 1,660 g (Table 1). The data indicate a trend where fish in larger ponds displayed higher body weights, suggesting that increased space and potentially better resource availability in these environments contributed to better growth and overall health.

Table 1. Morphometric measurements of the African catfish (*Clarias gariepinus*).

S/N	SL (cm)	BW (g)	Log SL	Log BW
1	59	2000	1.770852	3.30103
2	59.3	2000	1.773055	3.30103
3	58.6	1900	1.767898	3.278754
4	56	1800	1.748188	3.255273
5	51.1	1400	1.708421	3.146128
6	50.8	1400	1.705864	3.146128
7	54.6	1500	1.737193	3.176091
8	51	1500	1.70757	3.176091
9	52.1	1500	1.716838	3.176091
10	54.5	1600	1.736397	3.20412

A positive correlation ($R^2 = 0.9118$) was observed between standard length and body weight in the sampled fish (Figure 1). For example, sample 2, which had the highest SL (59.3

cm), also had one of the highest BW (2,000 g). Conversely, samples with lower standard lengths, such as samples 5 and 6, also had lower body weights (1,400 g). This correlation underscores the importance of adequate breeding space, as fish from larger ponds generally exhibited both greater lengths and higher weights, indicative of optimal growth conditions.

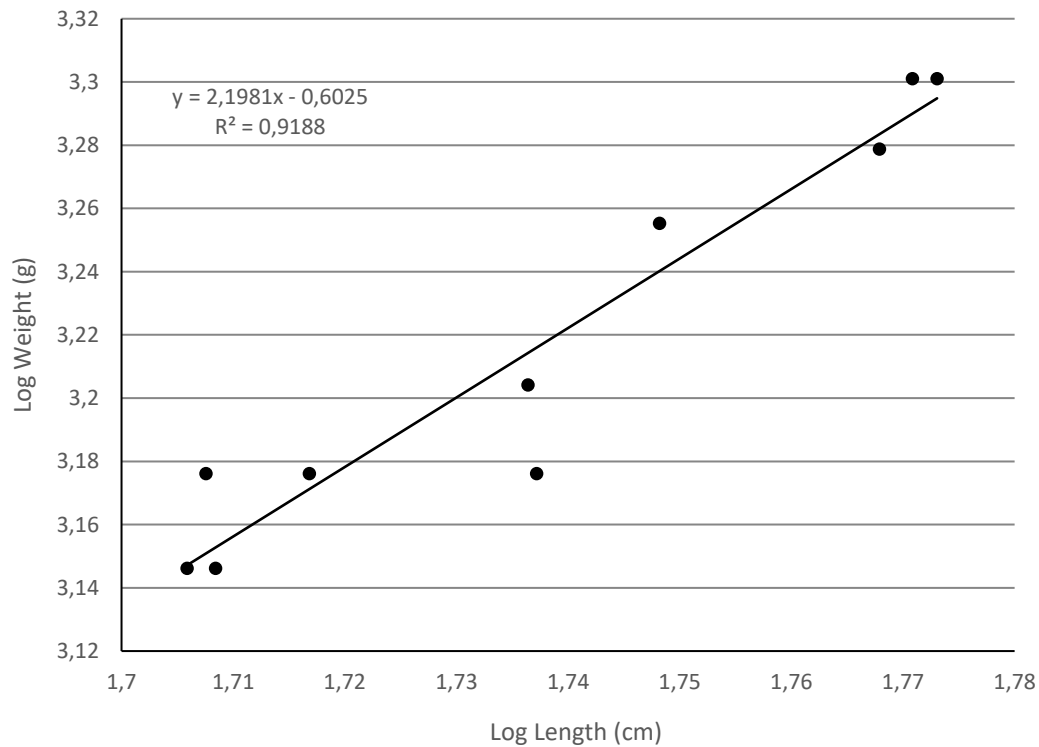


Fig. 1. Length-weight relationship of the African catfish (*Clarias gariepinus*).

Reproductive metrics

The Gonadosomatic Index (GSI) values for the sampled *Clarias gariepinus* ranged from 0.2 to 5.0. Sample 1, which had a GSI of 5.0, indicated the highest sexual maturity among the females, suggesting readiness for spawning. In contrast, sample 2 had the lowest GSI of 0.2, indicating a low level of sexual maturity, possibly due to recent spawning or sterility. The average GSI across all samples was approximately 3.09. This variation in GSI suggests that pond size and other environmental factors may have influenced the sexual maturity of the fish, with higher GSI values potentially linked to better growth conditions in larger ponds. The gonad weights varied significantly between the fish, with egg sacs ranging from 40.0 g to 100.0 g. Sample 1 had the heaviest egg sac at 100.0 g, which corresponds to its high GSI, further indicating advanced sexual maturity. Sperm sacs were observed in only two male fish (samples 2 and 7), with weights of 5.2 g and 10.1 g, respectively. The absence of sperm sacs in the other males could suggest a range of maturity stages or different spawning times.

The genital papilla length was measured in samples 2 and 7, where values of 1.8 cm and 2.7 cm were recorded, respectively. The longer papilla in sample 7, coupled with the higher sperm sac weight, suggests a more mature reproductive state compared to sample 2.

The absence of papilla in the other males could indicate either a non-visible state at the time of sampling or variability in maturity.

The cloaca width in female fish varied from 0.7 cm to 1.3 cm. The widest cloaca, at 1.3 cm, was observed in sample 3, which also had a relatively high GSI of 3.1. This suggests that a wider cloaca may be associated with greater reproductive readiness. Conversely, samples with narrower cloacas, such as sample 6 (0.7 cm), exhibited lower GSI values, implying less reproductive activity or immaturity.

There was a notable relationship ($R^2 = 0.946$) between GSI and gonad weight, particularly among the females (Figure 2). For instance, sample 1, with the highest GSI of 5.0, also had the heaviest egg sac at 100.0 g. This relationship suggests that GSI is a reliable indicator of reproductive status, with higher GSI values reflecting more developed gonads. Similarly, the length of the genital papilla in males and cloaca width in females also appeared to correlate with the reproductive metrics, further highlighting the connection between morphometric and reproductive parameters in *Clarias gariepinus*.

Hepatosomatic Index (HSI)

The liver weight (L.W) of the ten sampled *Clarias gariepinus* varied considerably, ranging from 10.0 g to 30.0 g. The heaviest liver was recorded in sample 5, weighing 30.0 g, while the lightest was observed in sample 4, at 10.0 g. The average liver weight across all samples was approximately 15.3 g. This variation in liver weight may reflect differences in the energy reserves among the fish, as liver size is often associated with the nutritional and metabolic status of the organism. Fish with higher liver weights, such as sample 5, may have had better access to food or more efficient energy storage, while those with lower weights could indicate insufficient feeding or higher energy expenditure.

The Hepatosomatic Index (HSI) values for the sampled fish ranged from 0.6 to 3.7. Sample 10 had the highest HSI at 3.7, indicating a substantial amount of energy reserves stored in the liver, which is reflective of high feeding activity.

Table 2. Reproductive metrics of *Clarias gariepinus*.

Sample No.	Gonad Weight (g)	Length of Genital Papilla (cm)	Cloaca Width (cm)	Liver Weight (g)	GSI	HSI
1	100.0 (Egg sac)	-	1.0	20.0	5.0	1.0
2	5.2 (Sperm sac)	1.8	-	15.0	0.2	0.7
3	60.0 (Egg sac)	-	1.3	12.0	3.1	0.6
4	80.0 (Egg sac)	-	1.0	10.0	4.4	0.6
5	40.0 (Egg sac)	-	0.8	30.0	2.8	2.1
6	54.0 (Egg sac)	-	0.7	18.0	3.8	1.2
7	10.1 (Sperm sac)	2.7	-	17.8	0.6	1.1

Sample No.	Gonad Weight (g)	Length of Genital Papilla (cm)	Cloaca Width (cm)	Liver Weight (g)	GSI	HSI
8	62.0 (Egg sac)	-	1.0	11.8	4.1	0.7
9	48.0 (Egg sac)	-	0.9	10.6	3.2	0.7
10	60.0 (Egg sac)	-	0.9	11.8	3.7	3.7

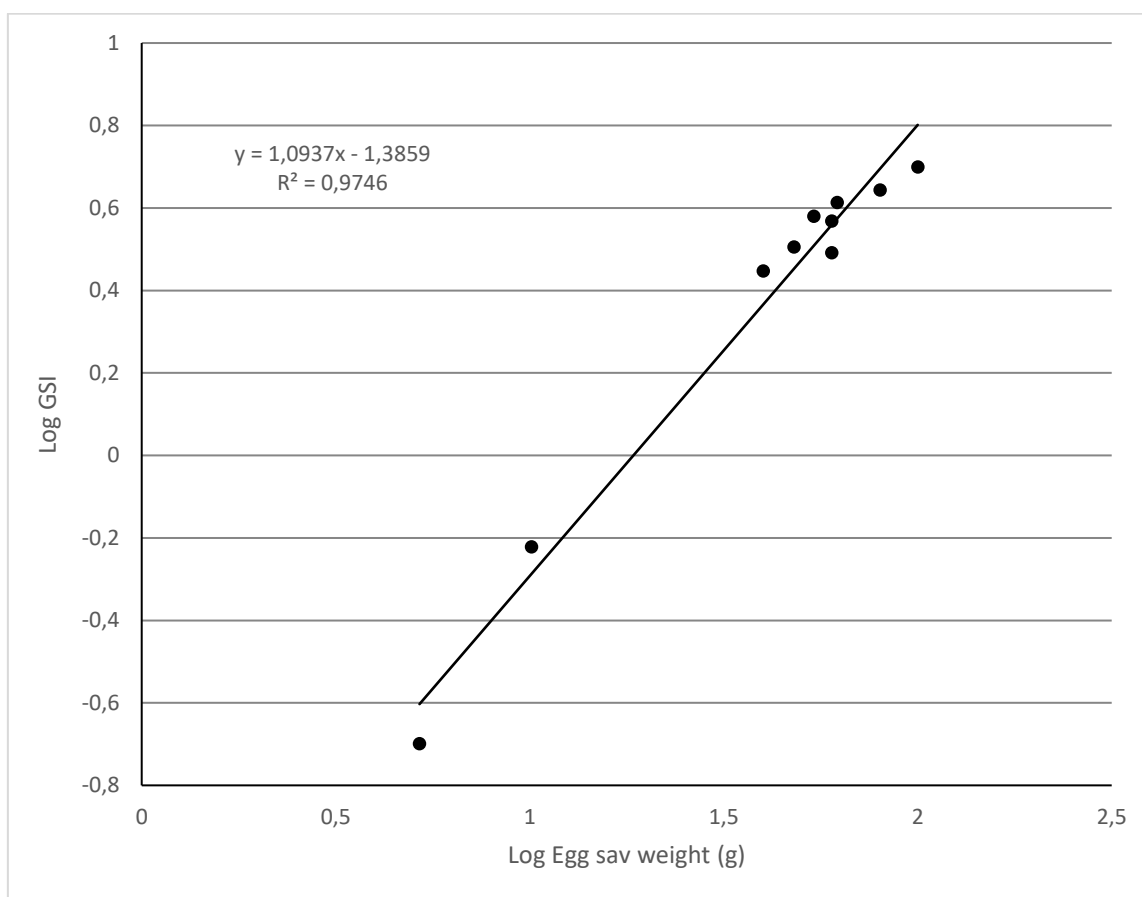


Fig. 2. Relationship between egg sac weight and Gonadosomatic index of *Clarias gariepinus*.

Conversely, samples 3 and 4 had the lowest HSI values of 0.6, suggesting lower energy reserves and possibly poor feeding activity. The average HSI across all samples was approximately 1.56. The observed differences in HSI suggest variability in the nutritional status and energy metabolism of the fish, potentially influenced by factors such as pond size, competition for food, and overall health. Fish with higher HSI values, such as samples 5 and 10, likely experienced better growth conditions and had access to more abundant or higher-quality food sources, leading to greater energy storage in the liver. On the other hand, lower HSI values, such as those seen in samples 3 and 4, may indicate less favorable conditions,

possibly due to limited food availability or increased stress, which could have led to reduced energy storage and lower overall health.

Comparative analysis

The analysis of the relationship between Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI) reveals a complex interaction between reproductive readiness and energy reserves in *Clarias gariepinus*. The data show that fish with higher GSI values, which indicate greater sexual maturity, often exhibited higher HSI values. For example, sample 1, with the highest GSI of 5.0, also had an HSI of 1.0. This suggests that fish with advanced reproductive stages tended to have better energy reserves, potentially supporting more successful reproductive outcomes. Conversely, fish with lower GSI values, such as sample 2 with a GSI of 0.2, also had a lower HSI of 0.7, indicating lower energy reserves and less optimal conditions for reproduction. This correlation suggests that higher energy reserves, as reflected by a higher HSI, may support greater reproductive development, as indicated by higher GSI values. However, the relationship is not perfectly linear, as some fish with high GSI values did not have correspondingly high HSI values (Figure 3).

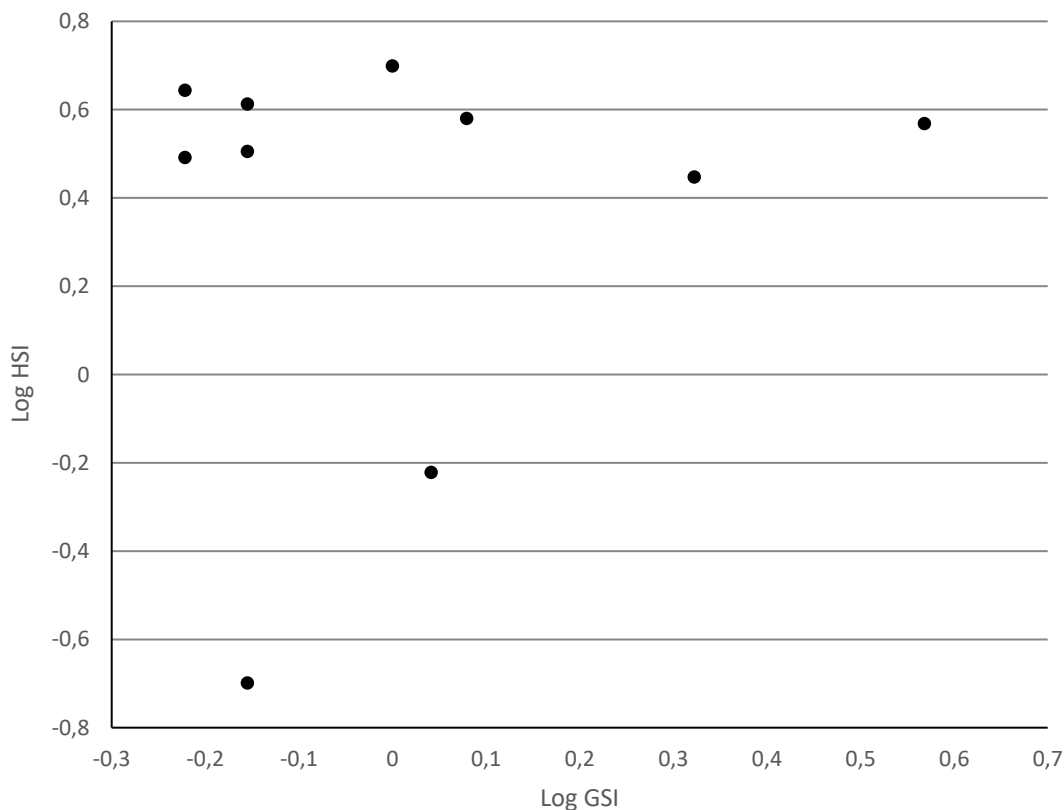


Fig. 3. Relationship between gonadosomatic index and hepatosomatic index of *Clarias gariepinus*.

This variability could be due to other influencing factors such as individual metabolic rates, pond conditions, or recent reproductive activity. The overall health of the fish, as

indicated by the liver weight (L.W), Hepatosomatic Index (HSI), and Gonadosomatic Index (GSI), appears to be influenced by pond size. Fish from larger ponds generally displayed higher values for both liver weight and HSI, indicating better overall health and more substantial energy reserves.

For instance, sample 5, from a larger pond, had the highest liver weight (30.0 g) and a relatively high HSI (2.1), suggesting improved growth conditions and energy storage. Similarly, sample 10, with a high HSI of 3.7, likely benefited from a larger pond environment that supported better feeding and energy accumulation. In contrast, fish from smaller ponds or less optimal environments exhibited lower liver weights and HSI values. For example, sample 4 had a liver weight of 10.0 g and an HSI of 0.6, indicative of reduced energy reserves and potentially poorer health conditions. These findings suggest that smaller ponds may limit growth opportunities, restrict access to food, and lead to decreased energy reserves, ultimately affecting the overall health and reproductive success of the fish.

The data imply that pond size plays a critical role in supporting the nutritional and reproductive needs of *Clarias gariepinus*. Larger ponds seem to provide better conditions for growth and energy storage, which in turn positively impacts reproductive metrics like GSI. Ensuring adequate pond size and resources could, therefore, be crucial for optimizing the health and productivity of fish in aquaculture settings.

4. DISCUSSION

The morphometric measurements in this study demonstrated significant differences in the standard length and body weight of *Clarias gariepinus* across varying pond sizes. Fish from larger ponds showed greater lengths (50.8 cm to 59.3 cm) and weights (1400 g to 2000 g), suggesting that pond size critically influences growth by providing more space, reduced competition, and better resource availability. These findings align with earlier research by Fagbenro and Adebayo (2005) and Adewumi and Olaleye (2011), who emphasized that larger ponds promote enhanced growth performance due to improved water quality and natural behaviors, growth is positively influenced. Similarly, Ekpo *et al.* (2021a), Ekpo *et al.* (2021b), and Solomon *et al.* (2013) noted that growth is affected by the rearing environment, including pond size and feeding regimes. However, growth is multifactorial, requiring consideration of stocking density and feeding alongside space, as supported by Ekpo *et al.* (2018), Ekpo *et al.* (2017), and Adeparusi *et al.* (2010). This underscores the importance of optimizing pond size for maximizing growth and productivity.

Reproductive metrics, particularly the Gonadosomatic Index (GSI), varied notably among samples, with values ranging from 0.2 to 5.0. Fish in larger ponds generally exhibited higher GSI, indicating greater reproductive maturity, consistent with findings by King and Udo (1998), who linked higher GSI with less crowded environments that reduce stress and improve nutrition. Yalcin *et al.* (2001) also emphasized environmental factors such as pond size and water quality in enhancing reproductive health. Furthermore, the positive correlation between GSI and Hepatosomatic Index (HSI) in this study highlights the crucial role of liver energy reserves in reproduction.

Saliu *et al.* (2007) similarly reported that adequate energy stores support reproductive processes. Conversely, low GSI values may reflect recent spawning or suboptimal conditions, reinforcing observations by Adebayo and Fagbenro (2004). Overall, the data emphasize that

larger ponds create conducive environments for reproductive development, though other factors like feeding and stocking density are also important.

The Hepatosomatic Index (HSI) results showed values between 0.6 and 3.7, with higher values linked to larger ponds and better energy reserves. This suggests pond size influences liver condition through improved feeding opportunities and reduced competition, consistent with Mfon and Solomon (2010) and Salu and Adekoya (2006). Lower HSI values in smaller ponds may indicate stress and poor feeding, as also noted by Adewumi and Olaleye (2011). The highest HSI recorded aligns with findings by Omotayo *et al.* (2012) showing that good nutrition and favorable environments promote energy storage. King and Udo (1998) further stressed the importance of proper pond management to sustain optimal HSI by maintaining water quality and food availability. Thus, pond size significantly affects liver health, which is vital for overall fish well-being.

An inverse relationship between GSI and HSI was observed, where fish with higher reproductive maturity tended to have lower liver energy reserves, reflecting energy allocation toward reproduction. This trade-off is supported by Akinsanya and Otubanjo (2006) and Ighwela *et al.* (2014), who noted energy shifts from storage to reproductive development. However, exceptions, such as fish maintaining high levels of both indices, suggest that optimal feeding and pond conditions can mitigate this trade-off (Ekpo *et al.* (2023a), Ekpo *et al.* (2023b), Fagbenro *et al.*, 2005).

Pond size profoundly impacts the health of *Clarias gariepinus*, with larger ponds supporting better growth, reproductive, and metabolic outcomes. These results align with reports by Adewolu and Adeniji (2008) and King and Jonathan (2003), linking larger ponds with improved water quality, reduced competition, and enhanced fish health. Nonetheless, fish in smaller ponds may still achieve good health metrics given effective management, as noted by Akinwale and Faturoti (2007). This study highlights that while pond size is critical, integrated management practices are essential to optimize aquaculture performance. Future research should further explore interactions between pond size, environmental conditions, and management to develop best practices for sustainable *Clarias gariepinus* farming.

Summary

This study examined the impact of breeding space, focusing on pond size, on the Gonadosomatic Index (GSI) and overall health of *Clarias gariepinus* (African catfish). Ten samples were analyzed for morphometric and reproductive parameters including standard length, body weight, liver weight, Hepatosomatic Index (HSI), and GSI. Findings revealed that larger pond sizes significantly enhanced liver weight, HSI, and GSI values, indicating improved energy reserves and feeding activity. These improvements correlated with greater reproductive readiness, suggesting that ample space positively influences both growth and reproductive health.

5. CONCLUSION

The study concludes that pond size plays a vital role in the health and reproductive efficiency of *Clarias gariepinus*. Fish raised in larger ponds demonstrated better liver condition and higher reproductive maturity, emphasizing the need to optimize pond dimensions for aquaculture success. Adequate space and resources are essential for sustainable fish farming

that maximizes growth and breeding potential. Recommendations include prioritizing larger pond sizes in aquaculture facilities, restructuring existing ponds where possible, and designing new ponds with sufficient dimensions. Regular monitoring of GSI, HSI, and liver weight is advised to track fish health and reproductive status. Tailored feeding strategies should support liver energy reserves, especially in confined spaces. Further research is encouraged to clarify how pond size affects reproductive metrics and to determine the best pond sizes for different growth stages.

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