ASSEMENT OF THE LENGTH -WEIGHT RELATIONSHIP AND CONDITION FACTOR OF *Clarias gariepinus* (Burchell 1822) RAISED IN INDOOR AQUAPONICS SYSTEM

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Globally, aquaculture production is the most immediate solution to declining capture fisheries, however, it also faces a number of challenges that prevent it from reaching its full potential (Barbu et al., 2016). Outdated culture systems and high cost of fish feeds resulting from competition of raw materials have been identified as major setbacks in the growth of aquaculture in most developing countries. Modern aquaculture technologies such as aquaponics system offer an opportunity for exploiting limited land and scarce water to farm fish and crops within the same system (Rurangwa and Verdegem, 2014) thus accelerating productivity. Aquaponics system offers an excellent alternative to traditional aquaculture practices that have struggled to intensify productivity. It is characterized by intensive fish production unit using a series of water treatment steps that include plants and filters for removing nutrients and impurities from water to facilitate its reuse (Espinal and Mutalic, 2019).

Aquaponics is an integrated system that combines the cultivation of aquatic organisms, such as fish, with the production of plants in a recirculating environment. In this system, the waste products from the fish are utilized as a source of nutrients for the plants, which in turn purify the water for the fish (Somerville et al., 2014). This symbiotic relationship not only reduces the environmental impact of traditional aquaculture but also increases the overall efficiency and productivity of the system.

A variety of plants can be grown within the aquaponics system under the hydroponic unit for nutrients uptake thus maintaining the integrity of water within the system for fish culture. Some of the plants grown under aquaponics systems include; Leafy vegetables (Spinach and Amaranth), Fruit vegetables (Cucumber and Eggplant), Root vegetables (Beets and Radishes) among other plants (Kim 2018). Okra has also been considered as one of the fruit vegetables that can be grown in aquaponics provided the necessary support system is provided.

Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*), are the most cultured species in Africa and have in previous studies demonstrated their candidature in aquaponics system (Ekawati et al., 2021; Love et al., 2015). The African catfish, *C. gariepinus* preference in aquaculture is as a result of its ability to tolerate high environmental temperatures and low dissolved oxygen thus making it a good candidate for intensive farming, (Safran, 2009). African Catfish is known for its hardiness and adaptability to various adverse environmental conditions. They are omnivorous and feed on a variety of organisms including fish and plant materials. *Clarias gariepinus* is an important food fish and one of the most important commercial freshwater species (Dadebo, 2000; Nyamweya et al., 2010). Studies have shown that, the African Catfish is also generally considered to be one of the most successful fish species in tropical aquaculture.

Under best management practices, *C. gariepinus* can be cultured intensively (Somerville et. al., 2014) under limited land and water resources (Huntington et al., 2017). Demand for *C. gariepinus,* both for food and as bait in capture fisheries has been increasing substantially in Africa (Omondi et al., 2001). The fish is also a vital source of revenue for fishermen and fish farmers and its farming is a source of occupation in developing nations (Felix et al.,2018). Because of the importance of the fish, it is important to place some importance on its growth patterns especially in an aquaponics system. This can only be done through the assessment of the length-weight relationship determination and the study of its condition factor. Typically, fish experience frequency growth variations as a result of some effects such as changes in nourishment composition, ecological factors, rate of reproducing among others. Length-weight relationships can be used to evaluate the influence of these factors (Suleiman, 2017). Length-weight relationships can be used to predict weight from length measurements (Muhammad et al., 2020). Length-weight relationship is an important biological factor in fisheries science as it assists in easy assessment of stock difference and overall well-being of fishes (Muhammad et al.,2020). Certainly, length and weight measurements can give data on the stock composition, lifespan, death, growth and production

(Konan et al., 2017). For production models, this key is used to forecast the biomass of the stock using fish lengths (Konan et al.,2017). The relationship of length-weight guesses state factor of the fish species and fish biomass through the length frequency (Fishbase,2013). Condition factor (K) is an assessment of overall welfare of fish and is based on the hypothesis or assumption that heavier fish are in good condition than the lighter ones (Ogamba et al., 2014). The condition factor of one or greater than one indicates the better state of fish however value less than one show bad state of fish (Abobi, 2015). Condition factor can be influenced by time of year, sex, type of nourishment, organism consumed by fish, oldness of fish, amount of fat reserved, and ecological conditions (Mon et al., 2020).

Several studies have investigated the length-weight relationship and condition factor of *Clarias gariepinus* in various aquaculture settings, but limited research has been conducted on these parameters in the context of indoor aquaponics systems. For example, Hossain et al. (2006) studied the length-weight relationship and condition factor of *Clarias gariepinus* in ponds and observed a strong positive correlation between length and weight, as well as high condition factor values, indicating a healthy fish population. Similarly, Haruna and Bichi (2017) reported a positive length-weight relationship and high condition factor for *Clarias gariepinus* raised in earthen ponds in Nigeria.

In the context of aquaponics, Endut et al. (2010) investigated the growth performance of *Clarias gariepinus* in an aquaponics system and found that the fish exhibited a positive length-weight relationship and high condition factor, suggesting that the aquaponics environment was suitable for their growth and development. However, the study focused on an outdoor aquaponics system, and more research is needed to understand the specific growth characteristics of *Clarias gariepinus* in indoor aquaponics systems.

1.2 PROBLEM STATEMENT

Aquaculture has become an increasingly important sector in addressing the growing global demand for protein-rich foods. Among the various aquaculture species, the African catfish

(*Clarias gariepinus*) has gained significant attention due to its adaptability, fast growth rate, and high market value (Raji et al., 2019; Adewumi and Olaleye, 2011). As the world's population continues to rise, the need for efficient and sustainable food production systems has become increasingly important. Aquaponics, an integrated system that combines aquaculture and hydroponics, has emerged as a promising approach to address this challenge (Blidariu and Grozea, 2011; Somerville et al., 2014).

In aquaponics, the waste products from the cultured aquatic organisms, such as fish, are utilized as a source of nutrients for the plants, which in turn purify the water for the fish (Somerville et al., 2014). This symbiotic relationship not only reduces the environmental impact of traditional aquaculture but also increases the overall efficiency and productivity of the system. However, the unique environmental conditions and management practices associated with indoor aquaponics systems may influence the growth and overall condition of the cultured fish species, warranting further investigation.

Despite the growing interest in aquaponics, limited research has been conducted on the length-weight relationship and condition factor of *Clarias gariepinus* raised in indoor aquaponics systems. Most of the existing studies on these parameters have focused on wild-caught or pond-reared African catfish (Adewumi and Olaleye, 2011; Raji et al., 2019). However, the unique environmental conditions and management practices associated with indoor aquaponics systems may influence the growth and overall condition of the fish, warranting a more in-depth investigation.

One of the key problems in understanding the length-weight relationship and condition factor of Clarias gariepinus in indoor aquaponics systems is the lack of empirical data. The majority of the existing studies on these parameters have been conducted on wild-caught or pond-reared populations of the African catfish, which may not accurately represent the growth and health dynamics of the species in the controlled environment of an indoor aquaponics system.

In wild or pond-reared populations, the fish are exposed to a wide range of environmental factors, such as seasonal variations, available food sources, and predation, which can significantly influence their growth and overall condition (Adewumi and Olaleye, 2011; Raji et al., 2019). In contrast, indoor aquaponics systems provide a more controlled environment, with the potential to manipulate key water quality parameters, such as pH, temperature, dissolved oxygen, and ammonia, to optimize the growth and health of the cultured fish (Blidariu and Grozea, 2011; Somerville et al., 2014).

The limited research on the length-weight relationship and condition factor of *Clarias gariepinus* in indoor aquaponics systems also raises concerns about the applicability of the existing models and indices developed for wild-caught or pond-reared populations. These models may not accurately reflect the growth and health dynamics of the fish in the unique environment of an indoor aquaponics system, leading to potential inaccuracies in stock assessment, fisheries management, and the optimization of aquaculture practices.

Moreover, the lack of empirical data on the length-weight relationship and condition factor of *Clarias gariepinus* in indoor aquaponics systems also hinders the development of more efficient and sustainable aquaculture practices. Understanding these parameters can provide valuable insights into the growth patterns, nutritional status, and overall health of the cultured fish, which can inform the optimization of feeding regimes, stocking densities, and other management practices (Hossain et al., 2006; Froese, 2006).

Another problem associated with the lack of research on the length-weight relationship and condition factor of *Clarias gariepinus* in indoor aquaponics systems is the potential impact on the economic viability and environmental sustainability of the aquaculture industry. Inefficient aquaculture practices can lead to increased production costs, reduced yields, and negative environmental impacts, such as water pollution and resource depletion (Blidariu and Grozea, 2011; Somerville et al., 2014).

By addressing the knowledge gap in the length-weight relationship and condition factor of *Clarias gariepinus* in indoor aquaponics systems, researchers can contribute to the development of more efficient and sustainable aquaculture practices. This, in turn, can lead to increased productivity, improved resource utilization, and reduced environmental impact, ultimately supporting the long-term viability of the aquaculture industry and its ability to meet the growing global demand for protein-rich foods.

1.3 JUSTIFICATION

The African catfish, *Clarias gariepinus*, is a widely cultured freshwater fish species known for its hardiness, rapid growth, and high market demand (Hossain et al., 2006). As the global population continues to grow, there is an increasing need to develop sustainable and efficient aquaculture practices to meet the rising demand for protein-rich foods (Mungkung et al., 2013). One approach that has gained attention in recent years is aquaponics, which integrates aquaculture and hydroponics to create a closed-loop system where the waste products from fish farming are used to cultivate plants (Goddek et al., 2015).

Aquaponics has the potential to provide numerous benefits, including water conservation, reduced waste discharge, and the production of both fish and plant crops (Somerville et al., 2014). However, the performance and growth characteristics of fish raised in aquaponics systems may differ from those raised in traditional aquaculture systems due to the unique environmental conditions and nutrient dynamics (Endut et al., 2010). Therefore, it is important to investigate the length-weight relationship and condition factor of *Clarias gariepinus* in the context of indoor aquaponics systems.

The length-weight relationship is a widely used tool in fisheries management and aquaculture to provide insights into the overall health and growth patterns of a fish population (Froese, 2006). This relationship is typically expressed as the equation W = aL^b, where W is the weight of the fish, L is the length of the fish, and a and b are the regression coefficients (Pauly, 1983). The condition factor, also known as the Fulton's condition factor, is a metric that reflects the overall 'well-being' or 'plumpness' of a fish, and is calculated as K = (W/L^3) x 100, where W is the weight of the fish and L is the length of the fish (Froese, 2006).

By studying the length-weight relationship and condition factor of *Clarias gariepinus* raised in an indoor aquaponics system, researchers can gain valuable insights into the growth and health of the fish under these unique environmental conditions. This information can be used to optimize the management and performance of the aquaponics system, as well as to compare the growth characteristics of *Clarias gariepinus* in aquaponics systems to those in traditional aquaculture systems.

Indoor aquaponics systems offer several advantages over outdoor systems, including better control over environmental parameters, reduced risk of disease and pests, and the potential for year-round production (Goddek et al., 2015). However, the unique environmental conditions, such as artificial lighting, temperature regulation, and nutrient dynamics, may impact the growth and health of the fish in ways that differ from outdoor systems.

By conducting a study on the length-weight relationship and condition factor of *Clarias gariepinus* raised in an indoor aquaponics system, researchers can contribute to the growing body of knowledge on the performance and suitability of this fish species for aquaponics production. The findings can inform the development of best practices for *Clarias gariepinus* culture in indoor aquaponics systems, as well as provide a basis for comparison with other aquaculture systems.

Moreover, the results of this study can have broader implications for the optimization and expansion of aquaponics technology as a whole. By understanding the growth characteristics of a key aquaculture species like *Clarias gariepinus* in an indoor aquaponics system, researchers can help to identify the optimal conditions and management strategies for successful aquaponics production, which can ultimately contribute to the development of more sustainable and efficient food production systems.

The proposed topic on the length-weight relationship and condition factor of *Clarias gariepinus* raised in an indoor aquaponics system is a timely and relevant area of research that can contribute to the growing field of aquaponics and sustainable aquaculture. The findings can provide valuable insights into the performance and suitability of this fish species for indoor aquaponics production, as well as inform the development of best practices and optimization strategies for aquaponics systems in general.

1.4 AIM AND OBJECTIVES

1.4.1 Aim

The aim of this study to assess growth patterns and health condition of *C. gariepinus* cultured in indoor aquaponics system using the length-weight relationship and condition factor approach.

1.4.2 Objectives

The specific objectives of the study are as follows:

i. Determine fish growth patterns (Isometric or Allometric) throughout the culture period.
ii. Obtain data for important key water quality variables in the aquaponics system throughout the culture period.
iii. Determine using the Fulton`s equation, the state of the cultured fish health (Condition factor).

1.5 SIGNIFICANCE OF THE STUDY

Understanding the length-weight relationship and condition factor of fish species is important for various aspects of aquaculture research and management. The length-weight relationship provides information about the growth pattern of the fish, which can be used to estimate the weight of the fish from its length measurements (Froese, 2006). This relationship is often expressed by the equation W = aL^b, where W is the weight of the fish, L is the length, and a and b are constants. The value of the exponent b provides insights into the growth pattern, with $b = 3$ indicating isometric growth, $b < 3$ indicating negative allometric growth, and $b > 3$ indicating positive allometric growth (Froese, 2006). The condition factor can provide information about the feeding, reproductive, and environmental status of the fish, as well as their overall fitness (Froese, 1975; Bagenal and Tesch, 1978).

Aquaponics is a sustainable food production system that integrates aquaculture (the farming of aquatic organisms) and hydroponics (the cultivation of plants in water) (Rakocy et al., 2006). Understanding the growth and condition of the fish in an aquaponics system is crucial for optimizing the system's productivity and maintaining the overall health of the fish. *Clarias gariepinus* is an important aquaculture species in many parts of the world, including Africa, due to its high growth rate, disease resistance, and adaptability to various environmental conditions (Viveen et al., 1985). Evaluating the length-weight relationship and condition factor of this species in an aquaponics system can provide valuable insights into its suitability and performance in this type of integrated system. The indoor nature of the aquaponics system studied in this research is significant, as it allows for greater control over environmental factors such as temperature, water quality, and feed availability, which can influence the growth and condition of the fish (Rakocy et al., 2006). Comparing the length-weight relationship and condition factor of *C. gariepinus* in an indoor aquaponics system to those reported in other culture systems can contribute to a better understanding of the species' adaptability and performance in different production environments. The findings of this study can be used to inform the management and optimization of aquaponics systems, particularly in terms of stocking density, feeding regimes, and overall system design. This information can be valuable for both small-scale and commercial-scale aquaponics operations, contributing to the development and sustainability of this integrated food production approach.

The length-weight relationship and condition factor of *Clarias gariepinus* raised in an indoor aquaponics system is significant, as it can provide important insights into the growth and health of the fish in this integrated production system, and contribute to the optimization and sustainability of aquaponics as a whole.

1.6 LIMITATIONS OF THE STUDY

While this study provides valuable insights into the length-weight relationship and condition factor of *Clarias gariepinus* raised in an indoor aquaponics system, it is important to acknowledge several limitations that should be considered when interpreting the findings.

Firstly, the study was conducted in a single indoor aquaponics facility, which may limit the generalizability of the results to other aquaponics systems with different environmental conditions, system designs, or management practices. Factors such as water quality, feed composition, and stocking density can all influence the growth and condition of the fish, and these variables may differ across aquaponics operations.

Additionally, the study was limited to a relatively short duration, which may not capture the full scope of the fish's growth and condition over their entire life cycle. Longer-term studies spanning multiple production cycles would provide a more comprehensive understanding of the length-weight relationship and condition factor of *C. gariepinus* in aquaponics systems.

The sample size used in the study, while adequate for the statistical analyses, may not be sufficient to account for individual variations among the fish. Larger sample sizes would enhance the reliability and representativeness of the findings.

Finally, the study did not investigate the potential effects of seasonal or environmental changes on the length-weight relationship and condition factor of the fish. Such factors may play a significant role in the growth and health of *C. gariepinus* in aquaponics systems, particularly in outdoor or semi-controlled environments. Despite these limitations, the current study contributes valuable baseline information that can inform future research and the optimization of *C. gariepinus* production in indoor aquaponics systems.

CHAPTER TWO

LITERATURE REVIEW

This chapter focuses on the most relevant work done related to the topic from the accessible literature in order to provide a thorough picture of the field's current level of research.

2.1. Aquaponic in Sierra Leone

2.1.1. Introduction to Aquaponics

Aquaponics is an innovative and sustainable method of food production that combines aquaculture (raising fish) with hydroponics (growing plants without soil). This system creates a symbiotic environment where fish waste provides essential nutrients for plant growth, and plants help filter and purify the water for the fish (Baßmann et al., 2017). The closed-loop nature of aquaponics significantly reduces water usage compared to traditional farming methods, making it an environmentally friendly option (Maranga et al., 2023). Aquaponics systems can be implemented in various settings, including urban areas, making them ideal for small-scale and urban farming (Olanrewaju et al., 2022).

2.1.2. Current State of Aquaponics in Sierra Leone

In Sierra Leone, the adoption of aquaponics is still in its nascent stages. The country faces significant challenges in food security and sustainable agriculture due to factors such as soil degradation, climate change, and limited access to modern farming technologies (FOA et al., 2022). However, there is growing interest in aquaponics as a viable alternative to traditional farming methods. Pilot projects and small-scale systems have been initiated by various NGOs and local entrepreneurs to demonstrate the potential of aquaponics in improving food production and livelihoods. Indoor aquaponics systems offer several benefits that are particularly relevant to the context of Sierra Leone. These systems can be set up in urban and peri-urban areas, making efficient use of limited space and providing fresh produce close to consumers. Indoor systems also allow for year-round production, independent of seasonal variations and external weather conditions. This is crucial for ensuring a consistent supply of fresh vegetables and fish, contributing to improved nutrition and food security. Moreover, indoor aquaponics systems can be designed to use minimal water, which is a significant advantage in regions with water scarcity. The recirculating nature of aquaponics ensures that water is reused within the system, reducing the overall water footprint compared to traditional agriculture.

2.2. The African catfish (*Clarias gariepinus)*

2.2.1. Background on *Clarias gariepinus*

The African catfish (*Clarias gariepinus* Burchell, 1822) is a warm-water fish with increasing commercial importance worldwide. Due to its high tolerance about adverse water conditions, including low oxygen (Belão et al., 2011) and high ammonium, nitrite, and nitrate concentrations (Schram et al., 2014), the African catfish can be reared under high stocking densities (up to 500 kg m^{-3}) (van de Nieuwegiessen et al., 2009). *Clarias gariepinus*, is a species of freshwater fish native to Africa and parts of the Middle East. This species thrives in a variety of habitats, including rivers, lakes, and floodplains, and is known for its ability to tolerate low oxygen levels and high stocking densities (Palm et al., 2022). The African catfish is highly valued in aquaculture due to its rapid growth rate, high fecundity, and adaptability to different environmental conditions. Economically, it is one of the most important fish species in Africa, contributing significantly to food security and livelihoods (Afolabi et al., 2020). In research, *Clarias gariepinus* is frequently studied for its physiological and genetic traits, making it a model organism for various scientific investigations (Nóbrega et al., 2024).

2.2.2 Purpose and Scope

The primary objective of this review is to explore the length-weight relationship of *Clarias gariepinus* and its implications for fisheries management, aquaculture, and ecological studies. Understanding this relationship is crucial as it provides insights into the fish population's growth patterns, health status, and overall condition. By examining the length-weight relationship, researchers can develop better management practices to optimize the growth and yield of *Clarias gariepinus* in aquaculture systems.

2.2.3 Significance of the Length-Weight Relationship

The length-weight relationship is a fundamental aspect of fish biology that helps in assessing the growth performance and health of fish populations. For *Clarias gariepinus*, this relationship is particularly significant as it aids in determining the condition factor, which is an indicator of the fish's well-being and nutritional status (Langi et al., 2024). In fisheries management, understanding the length-weight relationship helps in setting appropriate fishing regulations and ensuring sustainable harvests. It also assists in monitoring the impact of environmental changes on fish populations and making informed decisions for conservation efforts.

In aquaculture, the length-weight relationship is used to optimize feeding strategies and improve the efficiency of fish farming operations. By analyzing this relationship, aquaculturists can adjust feed formulations and feeding schedules to enhance growth rates and reduce feed costs. Additionally, the length-weight relationship is valuable in ecological studies as it helps in understanding the dynamics of fish populations in natural habitats. It provides insights into the effects of habitat degradation, pollution, and climate change on fish growth and survival. Overall, the length-weight relationship of *Clarias gariepinus* is a critical tool for advancing both aquaculture practices and ecological research.

2.3. Theoretical Framework

2.3.1. Theoretical Basis of the Length-Weight Relationship

The length-weight relationship (LWR) in fish is a fundamental concept in fisheries science, providing insights into the growth patterns and overall health of fish populations. The relationship is typically expressed by the formula:

$$W = aL^b$$

where (W) represents the weight of the fish, (L) is the length, (a) is the intercept (a constant that varies among species), and (b) is the slope (an exponent that indicates the growth pattern of the fish) (Li et al., 2023). This power-law equation is often linearized using logarithmic transformation to facilitate statistical analysis:

$$\log (W) = \log (a) + b\log (L)$$

This transformation allows for a more straightforward interpretation and comparison of the growth parameters across different species and populations.

2.3.2. Biological Significance of the Length-Weight Relationship

The length-weight relationship is crucial for understanding the biological aspects of fish growth. The exponent (b) typically ranges between 2.5 and 3.5 for most fish species, indicating isometric or allometric growth (Wang et al., 2017). Isometric growth ((b = 3)) suggests that the fish grows proportionally in all dimensions, while allometric growth ((b \neq 3)) indicates that the fish's body shape changes as it grows (Li et al., 2023). This relationship helps in assessing the condition factor of fish, which indicates their health and nutritional status. A higher condition factor implies better health and well-being, while a lower condition factor may indicate poor health or environmental stress (Dikou, 2023).

2.3.3. Ecological Significance of the Length-Weight Relationship

Ecologically, the length-weight relationship provides valuable information about the population dynamics and habitat conditions of fish species. It helps in estimating the biomass of fish populations, which is essential for stock assessment and management. By analyzing the LWR, researchers can monitor the effects of environmental changes, such as pollution and habitat degradation, on fish populations. This relationship also aids in understanding the reproductive biology of fish, as changes in the LWR can reflect variations in reproductive output and success.

2.3.4. Applications in Fisheries Management and Aquaculture

In fisheries management, the length-weight relationship is used to set appropriate fishing regulations and quotas to ensure sustainable harvests. It helps in predicting the yield and biomass of fish stocks, which is crucial for maintaining ecological balance and preventing overfishing. In aquaculture, the LWR is employed to optimize feeding strategies and improve growth rates. By understanding the growth patterns of cultured fish, aquaculturists can adjust their practices to enhance production efficiency and reduce costs. Overall, the length-weight relationship is a vital tool for advancing both fisheries management and aquaculture practices.

2.4. Historical Context and Evolution of Knowledge on the Length-Weight Relationship of *Clarias gariepinus*

2.4.1. Landmark Studies

The study of the length-weight relationship (LWR) in *Clarias gariepinus*, commonly known as the African catfish, has a rich history marked by several landmark studies. Early research focused on understanding this species's fundamental biological and ecological aspects. One of the pioneering studies by Bagenal and Tesch (1978) laid the groundwork by establishing the fundamental principles of LWR in fish, which were later applied to *Clarias gariepinus* (Hadiza et al., 2023). Subsequent studies, such as those by Lizama and Ambrosio (2001), provided detailed analyses of the LWR in various fish species, including *Clarias gariepinus*, highlighting the importance of this relationship in fisheries science (Ayo-Olalusi, 2014).

2.4.2. Evolution of Knowledge

Over the years, the understanding of the LWR in *Clarias gariepinus* has evolved significantly. Early research primarily focused on descriptive studies, documenting the basic parameters of the LWR. For instance, a study by (Ayo-Olalusi (2014) examined the LWR and condition factor of *Clarias gariepinus* reared in flow-through system tanks, revealing positive allometric growth patterns (Shittu & Oguntoye, 2020) . This study was crucial in demonstrating the practical applications of LWR in aquaculture settings. More recent research has employed advanced statistical methods and larger datasets to refine the estimates of the LWR parameters, providing more accurate and reliable data for fisheries management (Tolulope, 2014) .

2.4.3. Geographical Variability

The LWR of *Clarias gariepinus* can vary significantly across different geographic locations and environments. For instance, a study by Fagbuaro et al. (2019) in Igbokoda, Ondo State, Nigeria, found that the (b) values for males and females were 2.625 and 2.764, respectively, indicating negative allometric growth (Fagbuaro et al., 2019). In contrast, Hadiza et al. (2023) reported higher (b) values in Jibia, suggesting that local environmental factors such as water quality and food availability can influence the growth patterns of *Clarias gariepinus*. These variations underscore the importance of considering geographic and environmental contexts when studying the LWR of this species.

2.4.4. Contributions to Current Knowledge

Past research has greatly contributed to the current understanding of the LWR in *Clarias gariepinus*. Studies have consistently shown that the LWR can vary significantly depending on environmental conditions, such as water quality and availability of food resources. For example, Hadiza et al., (2023) conducted a comprehensive study on the LWR and condition factor of *Clarias gariepinus* in Jibia Local Government Area, Katsina State, Nigeria, highlighting the influence of local environmental factors on the growth patterns of this species. These findings have been instrumental in developing region-specific management strategies for *Clarias gariepinus* populations.

2.4.5. Implications for Future Research

The evolution of knowledge on the LWR of *Clarias gariepinus* underscores the importance of continuous research in this field. Future studies are expected to build on the existing body of knowledge by incorporating new technologies, such as remote sensing and machine learning, to enhance LWR estimates' accuracy further. Additionally, there is a growing interest in exploring the genetic basis of growth patterns in *Clarias gariepinus*, which could provide deeper insights into the factors influencing the LWR. Overall, the historical context and evolution of knowledge on the LWR of *Clarias gariepinus* highlight the dynamic nature of this field and its critical role in advancing fisheries science and aquaculture practices.

2.5. Current Research and Trends on the Length-Weight Relationship of *Clarias gariepinus*

2.5.1. Recent Findings

Recent studies on the length-weight relationship (LWR) of *Clarias gariepinus* have provided valuable insights into the growth patterns and health status of this species. A study conducted by Hadiza et al. (2023) in Jibia Local Government Area, Katsina State, Nigeria, revealed that *Clarias gariepinus* exhibited a negative allometric growth pattern with regression exponent (b) values of 2.86, 2.91, and 2.88 for males, females, and combined sexes, respectively (Hadiza et al., 2023). This indicates that the fish grows more in length than in weight. Another study by Ayo-Olalusi (2014) on *Clarias gariepinus* reared in flow-through system tanks found positive allometric growth with (b) values of 3.358, 3.391, and 3.372 for males, females, and combined sexes, respectively (Ayo-Olalusi, 2014). These findings highlight the variability in growth patterns depending on the rearing conditions and environments.

2.6. Culture of *Clarias gariepinus* in Aquaponics Systems

2.6.1. Different Fish Species Cultured in Aquaponics Systems

Various fish species are suitable for aquaponics systems, each with its own set of requirements and benefits. Commonly cultured species include tilapia, catfish, koi, goldfish, trout, and perch. Tilapia is particularly popular due to its hardiness, rapid growth, and tolerance to a wide range of water conditions. Catfish, including *Clarias gariepinus*, are also favored for their adaptability and high growth rates. The choice of fish species often depends on the local climate, system design, and intended use of the fish, whether for consumption or ornamental purposes.

2.6.2. Culture of *Clarias gariepinus* in the NFT Aquaponics System of Okra

The Nutrient Film Technique (NFT) is a type of aquaponics system where a thin film of nutrient-rich water flows over the roots of plants, providing them with essential nutrients while maintaining oxygen levels. *Clarias gariepinus,* or African catfish, has been successfully cultured in NFT systems alongside crops like okra (*Abelmoschus esculentus*) *Clarias gariepinus,* or African catfish, has been successfully cultured in NFT systems alongside crops like okra (*Abelmoschus esculentus*) (Din et al., 2024). Studies have shown that using a combination of gravel and clay pebbles as growth media in NFT systems can enhance the growth and production of both catfish and okra (Din et al., 2024). The integration of *Clarias gariepinus* in NFT systems not only improves water quality through nutrient removal but also supports sustainable food production by providing a reliable source of protein and vegetables.

2.7 Research Gaps and Future Directions

2.7.1 Identified Gaps

Despite the extensive research on the length-weight relationship and condition factor of *Clarias gariepinus*, several gaps remain. One significant limitation is the geographical focus of existing studies, which are predominantly conducted in specific regions such as Nigeria (Fagbuaro et al., 2019; Hadiza et al., 2023). This regional bias limits the generalizability of findings to other environments and aquaponics systems globally. Additionally, most studies have focused on wild or traditional aquaculture settings, with limited research on indoor aquaponics systems (Davies et al., 2013). This gap is critical as indoor systems present unique environmental conditions that could influence the growth patterns and health of C. *gariepinus* differently.

Also, many existing studies are short-term, often spanning a few months. Long-term studies are necessary to understand the growth dynamics and condition factors over the entire lifecycle of the fish. Furthermore, there is a scarcity of research on the impact of different feed types and feeding regimes on the length-weight relationship and condition factor in indoor aquaponics systems. This aspect is crucial as diet significantly affects fish growth and health.

2.7.2 Future Research

Future research should address these gaps to advance the understanding of the length-weight relationship in *Clarias gariepinus*. Expanding the geographical scope of studies to include diverse regions and climates will help develop a more comprehensive understanding of how different environmental conditions affect the growth and health of C. *gariepinus*. Comparative studies between indoor aquaponics systems and traditional aquaculture settings across various regions would be particularly valuable.

Longitudinal studies are essential to capture the long-term growth patterns and condition factors of *C. gariepinus* in indoor aquaponics systems (Davies et al., 2013). These studies should span multiple years to provide insights into how growth rates and health indicators change over time. Additionally, research should explore the effects of different feed types and feeding regimes on the length-weight relationship and condition factor. Experimental studies comparing various diets and feeding frequencies can help identify optimal feeding strategies for indoor aquaponics systems.

Moreover, incorporating advanced methodologies such as genetic analysis and biometric monitoring can provide deeper insights into the factors influencing growth and condition. Genetic studies can help identify strains of C. *gariepinus* that are best suited for indoor aquaponics systems, while biometric monitoring can offer real-time data on growth and health parameters. Finally, interdisciplinary research combining aquaculture, environmental science, and technology can lead to innovative solutions for optimizing indoor aquaponics systems for C. *gariepinus*.

By addressing these research gaps and exploring new methodologies, future studies can significantly enhance our understanding of the length-weight relationship and condition factor of *Clarias gariepinus* in indoor aquaponics systems, ultimately contributing to more sustainable and efficient aquaculture practices.

MATERIALS AND METHOD

3.0 The Study Area

The study was carried out at the EU funded Living Lab in the Department of Aquaculture and Fisheries Management, School of Natural Resources Management, Njala University, Njala Campus from March to July 2024. Njala University is located in Kori Chiefdom, Moyamba District Southern Sierra Leone (Figure 1).

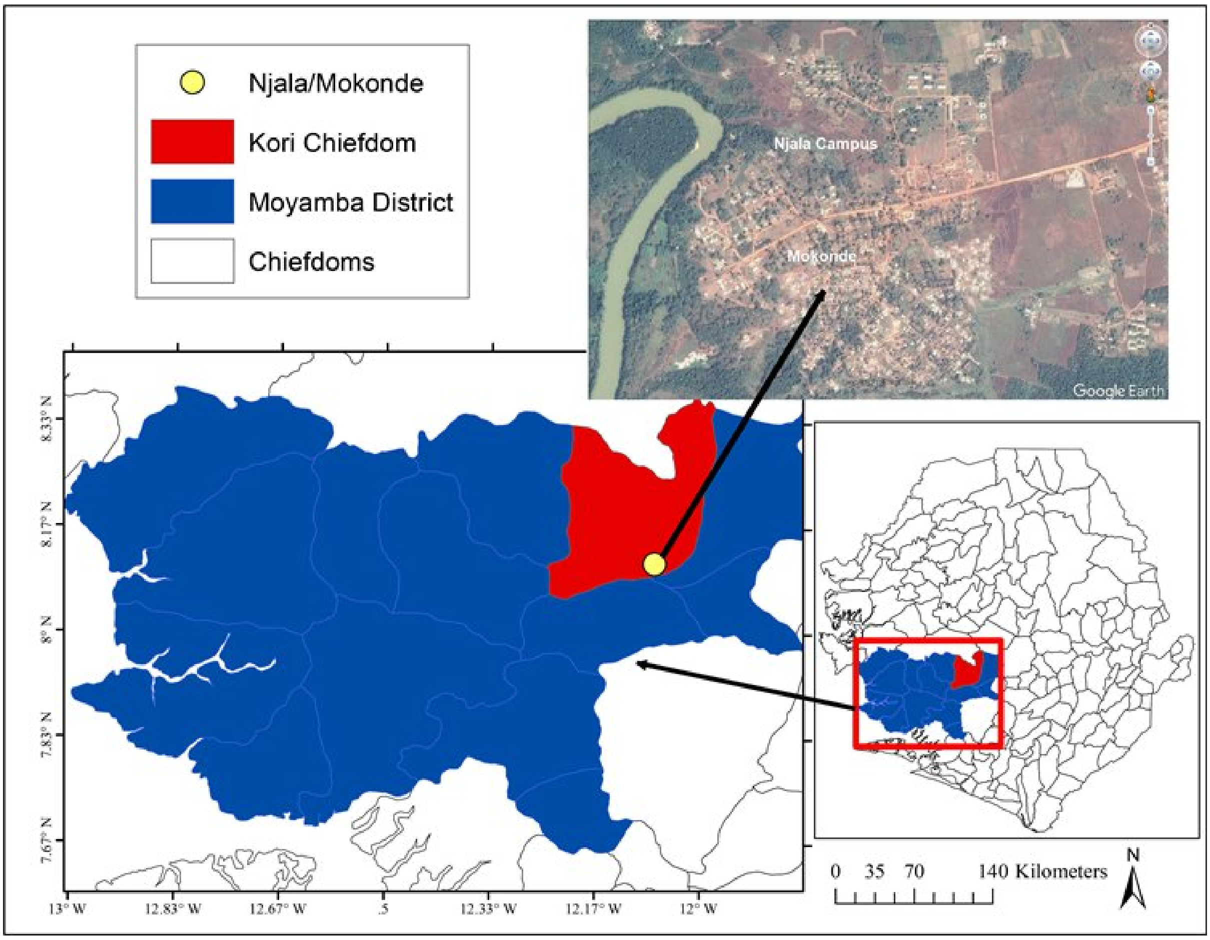

Figure 3.1. Map showing Sierra Leone (bottom right), Moyamba District, Kori Chiefdom (left), Njala campus, and Njala/Mokonde (top right). Excerpted from Barrie et al 2021.

3.2 Experimental procedure and data collection

3.2.1 Collection of fish samples

The African catfish used in this research were raised in an aquaponics systems. The system consisted of the sump, the NFT pipes in which okra was grown, the IBC fish tank (1000 L capacity), the sludge tank, the radial tank and the filter tank (Figure 2). Total fish sampling was carried out fortnightly for a period of five months from March to July 2024. Water in the tank was drained with lift pump every time sampling was done. Collected samples were taken immediately to the analytical table in the adjoining office.

Figure 3.2. Image of the experimental setup showing the IBC tank where fish was raised

3.2.2 Laboratory analysis

Morphometric measurements of the standard length, total length, and body weight of all fish samples were taken to the nearest 0.1 cm and 0.1 g from the tip of the head to the tip of the tail using a metre rule and a digital electronic weighing scale Model: EK3250 respectively. Fish morphometric data was written in the research laboratory logbook and subsequently transferred into an Excel sheet for analysis.

3.3 Determination of LWR and condition factor

The length-weight relationships (LWR) and condition factor of the experimental fish - *Clarias gariepinus* (Burchell 1822) were calculated with the equation put forth by Bagenal, as used by Olapade and Quinn (2019), and Le-Cren as used by Ayo-Olalusi (2014).

$$W = aL^b$$

Where

W is the observed total weights of the fish in grams.

L is the observed standard lengths in centimetres.

'**a**' is coefficient related to body form and

'**b**' is an exponent indicating isometric growth when equal to 3.0; negative allometry at < 3, positive allometry at > 3.

The logarithmic transformation of the equation $W = aL^b$ gives a straight-line relationship in the form

$$\text{Log } W = \text{Log } a + b \text{ Log } L.$$

The confidence interval (CI) of "b" was computed using the equation provided by Egbal et al., (2011): CI = b ± (1.96*SE) with SE = Standard error of 'b' Condition factor, K was derived following Pauly (1983)

3.3.1 Determination of Fulton`s Condition Factor (CF)

The Condition factor (K) of the fish was computed for the individual fish according to Le-Cren (1951), using the equation:

$$K = (W/W\hat{})$$

Where

K is the condition factor of the fish

W is the observed weight of the fish in grams and

W^ is the calculated weight of the fish in grams

3.3.2 Determination of Modified Condition Factor (MCF)

The modified Condition Factor of the fish was calculated using the equation put forth by Ricker (1975) as below.

$$K = 100W/L^b$$

3.3.3 Determination of Relative Condition Factor (Kn)

The Relative Condition Factor of the fish was calculated using the equation put forth by Le-Cren (1951) as below.

$$Kn = W/aLb$$

Where

W = weight of the fish

a = Intercept

b = Slope or regression coefficient and

L = Length of the fish

3.4 Sex determination and sex ratio

The sex of each fish specimen was determined by merely examining their sexual papillae, and were categorised into male or female for each sample. The ratio of males to females was determined at the end of the research period. The chi-square analysis was calculated for sex ratio using the equation:

$$X^2 = \frac{(Fi - fi)2}{F!}$$

Where,

Fi is the expected frequency

fi is the observed frequency,

3.5 Determination of Water quality Parameters

The quality of the water in which the fish was cultured was analysed for dissolved oxygen (DO), Temperature (ToC), pH, Nitrate, Total Dissolved Solids (TDS), Electrical Conductivity (EC) and Salinity. The assessment was carried out multi-parameter kits and probes. The essence of the water quality assessment is to provide backing for the condition factor, to prove the state of health of the fish.

3.5 Data analysis.

The data in this study were analysed using the Excel sheet. The chi-square test was performed on monthly and overall sex ratios of the population. One-way analysis of variance (ANOVA) was carried out to test for significant differences. Regression analysis was used to test for linear relationships.

3.6 Ethical and Environmental Considerations

The research complied with all ethical procedures in fish handling, and treatment especially during harvesting and morphometric analysis. The researcher was careful to release waste waters into the environment with discretion.

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Objective 1.

- **Determine growth patterns (Isometric or Allometric) of *C. gariepinus* throughout the culture period.**

Hypotheses

- H_O : b = 3 → H_O : "Isometric growth."
- H_a : b ≠ 3 → H_a : "Allometric growth."

This aspect of the results first present the objective and hypothesis tested during the study. The results obtained for length-weight relationship of the experimental fish, which answered the objective and validated the hypothesis are presented in Tables 4.1 – 4.3, and Figures 4.1 – 4.6. The combined b value obtained in this study is 2.8759, while the values for the male and female fish are 2.7649 and 3.0393 respectively. Growth patterns obtained for the male was negative allometric while that of the female was positive allometric growth.

Table 4.1. Monthly mean length-weight measurements of *C. gariepinus* (African Catfish)

	March	April	May	June	July
Total length (cm)	17.45	23.85	30.49	38.44	42.49
Standard length cm)	15.77	20.42	27.55	34.41	37.92
Weight (g)	41.31	103.03	222.42	403.84	541.94

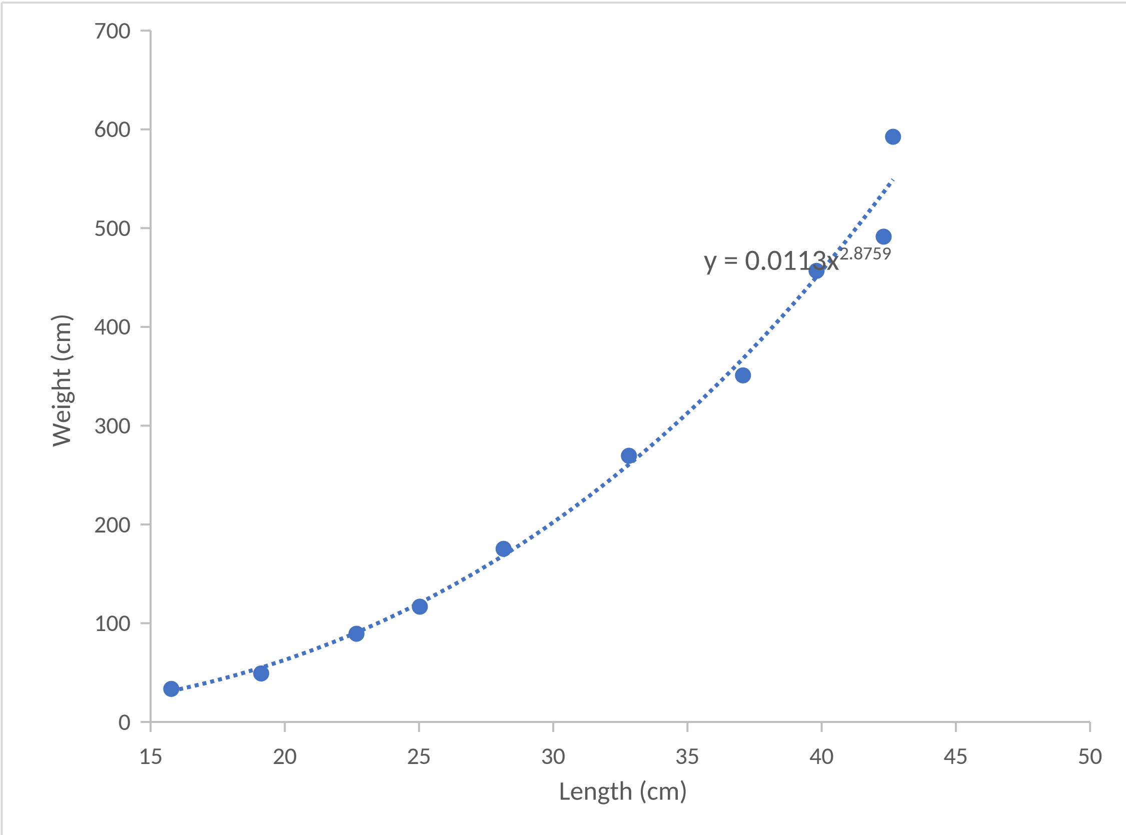

Figure 4.1. The combine length-weight of *C. gariepinus*

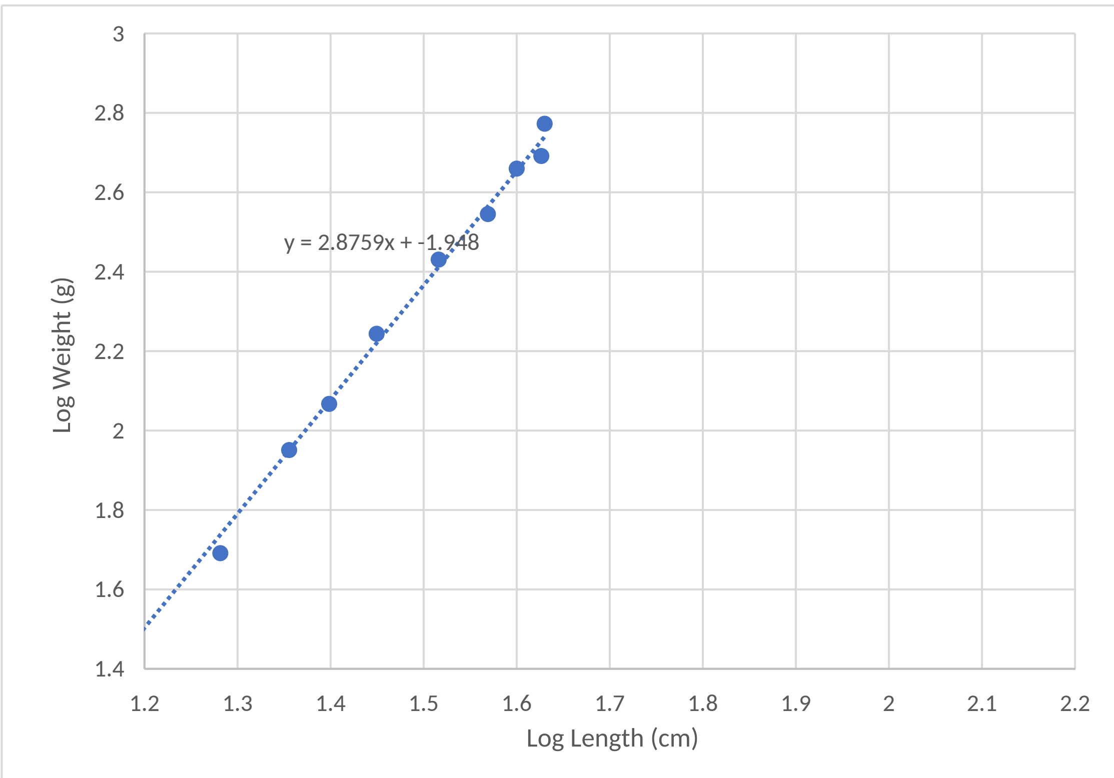

Figure 4.2. The log length of *C. gariepinus*

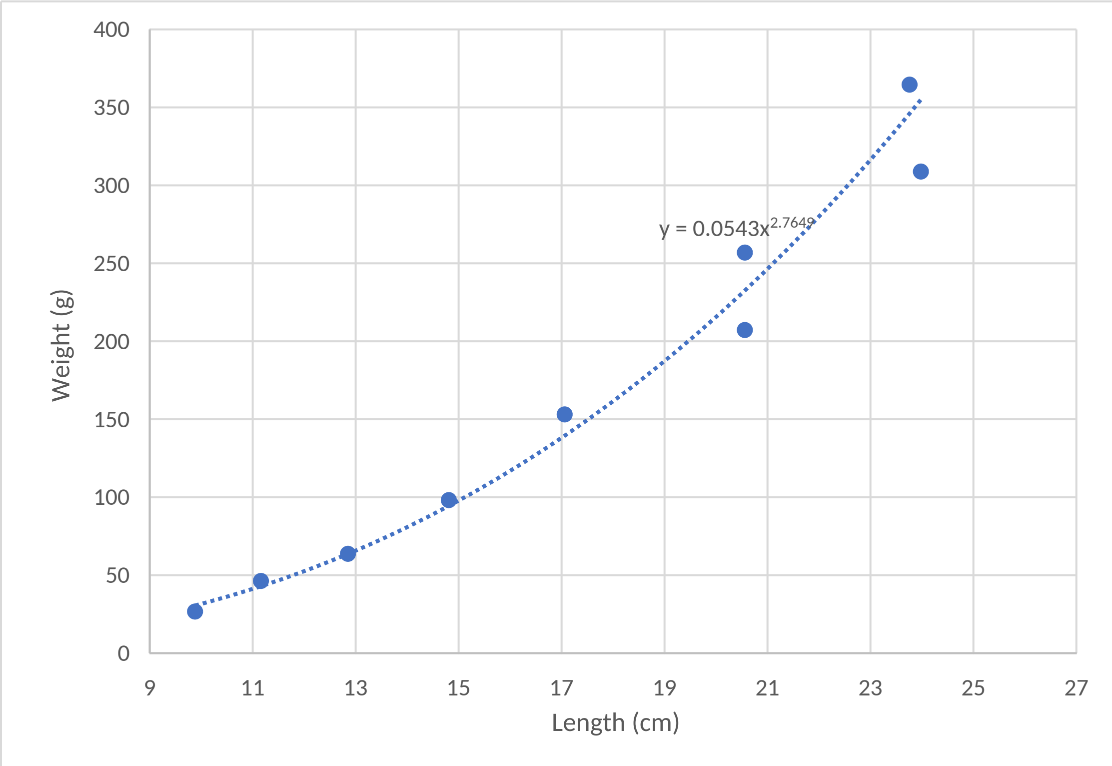

Figure 4.3. The length-weight of male *C. gariepinus*

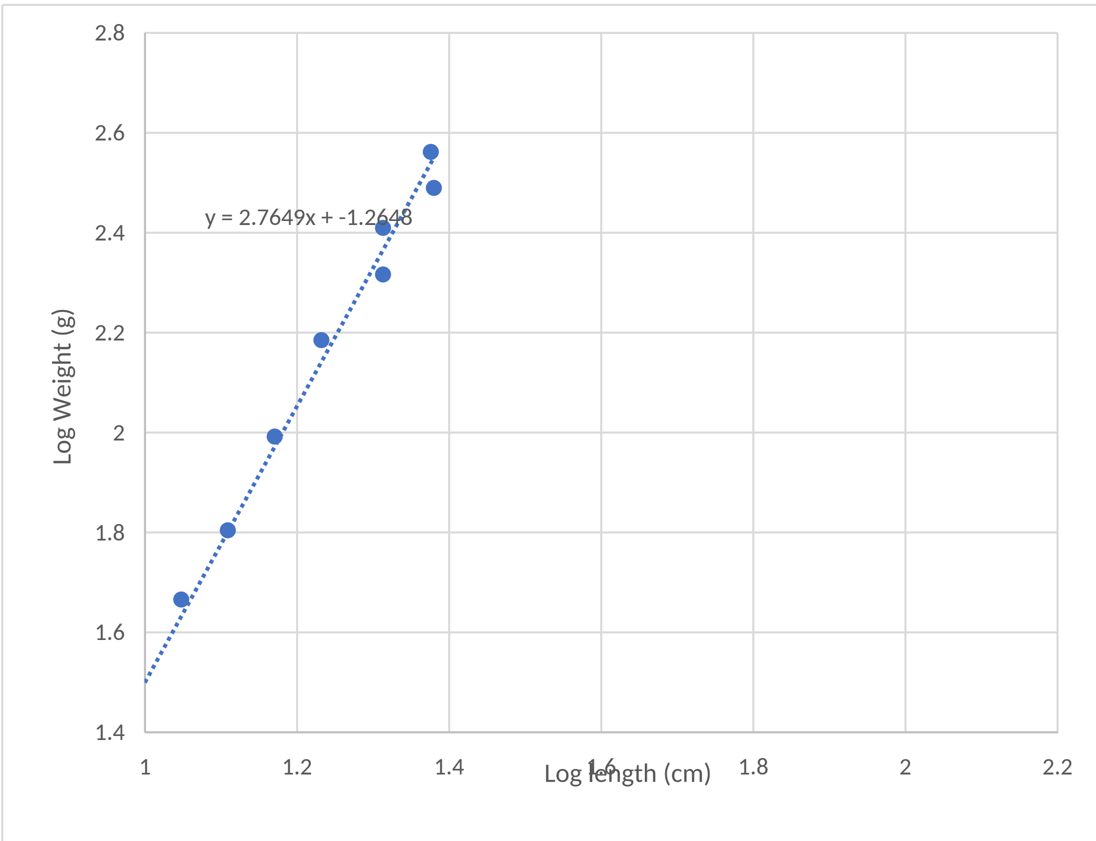

Figure 4.4. The log length of male *C. gariepinus*

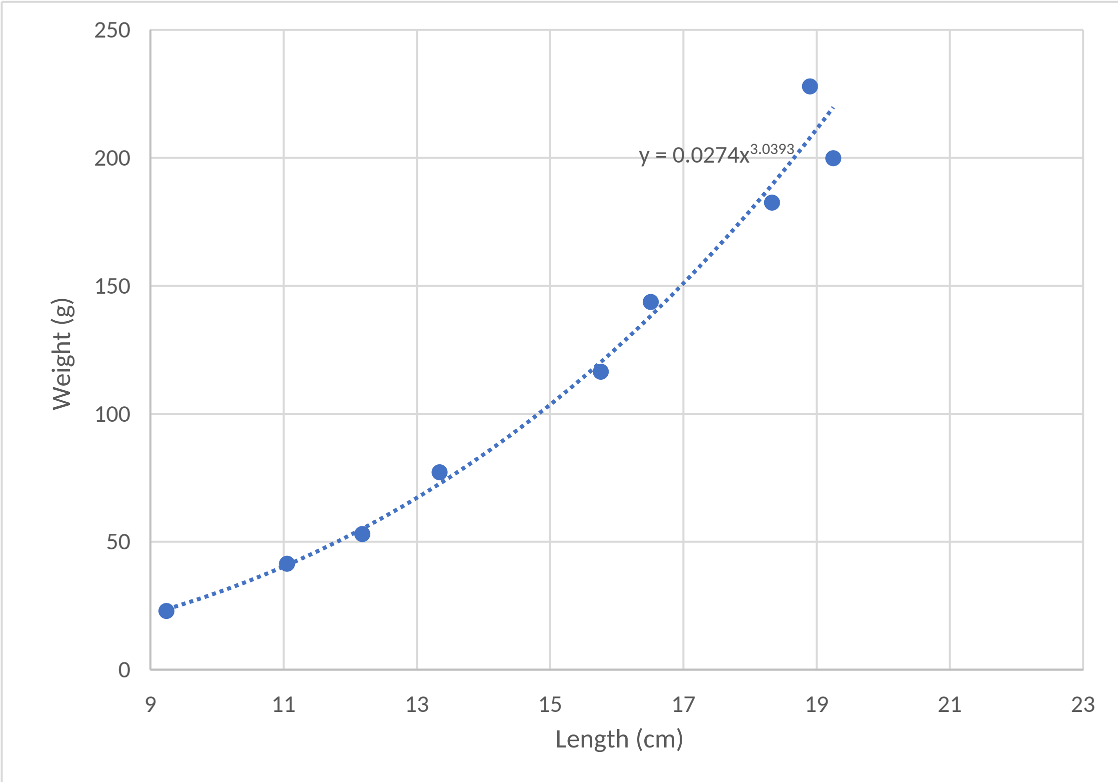

Figure 4.5. The length-weight of female *C. gariepinus*

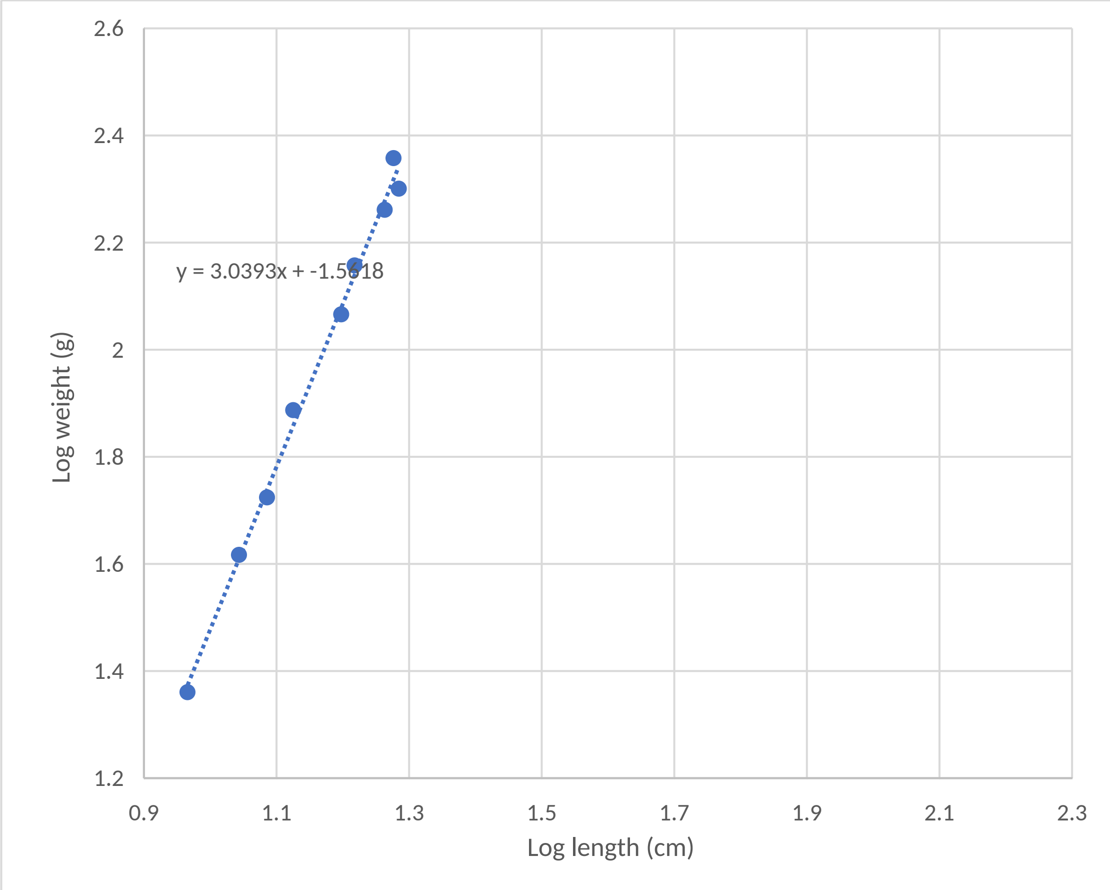

Figure 4.6. The log length of female *C. gariepinus*

Table 4.2. Descriptive statistics and regression parameters of *C. gariepinus* in the LL

Group	N	$W = aL^b$	Regression parameters		r
			a	**b**	
Male	21	170.27	0.054	2.765	0.988
Female	19	118.27	0.027	3.039	0.994
Combined	39	260.413	0.0113	2.876	0.996

Table 4.3. Comparative length-weight relationship of *C. gariepinus* by other researchers

Author	Sex	Intercept (a)	Slope (b)	r	r^2	Mean of K	Area of study
	C. gariepinus						
Fagbuaro et al., (2019)	Male	-1.7253	2.625	0.947	0.897	0.567 ±0.093	Igbokoda, Ondo State, Nigeria
	Female	-1.9890	2.764	0.919	0.844	0.644± 0.096	
Bubu-Davies et al., (2013)	Male	-57.81	7.74	0.78	0.00	1.06	Woji, Port Harcourt, Rivers State, Nigeria
	Female	-48.43	6.96	0.86	0.00	1.15	
	Combined	-65.78	7.87	0.90	0.00	1.10	

Olapade and Conteh (2019)	Combined	0.0183-0.075	2.74-3.37	0.00	0.831-0.963	0.95	Department of Aquaculture and Fisheries Management, Njala University, Njala Campus

N = number of samples, a = intercept/regression constant, b = the slope/regression coefficient, r = the correlation co-efficient, K = condition factor. NUSL = Njala University Sierra Leone

4.1.2 Objective 2.

- Determine using the Fulton`s equation, the state of the health of the cultured fish (Condition factor).
- **Hypotheses**
- $\mathbf{H_O}$: K = ≥1 → "The fish is in a state good health condition"
- $\mathbf{H_a}$: K ≠ 1 → "The fish is in bad health condition."

The results obtained for objective 2, the condition factor of the experimental fish, which answered the objective and validated the hypothesis are presented in Tables 4.4 – 4.5, and Figures 4.7 – 4.8.

The high K values of 1.002, 1.005 and 1.008 were obtained for combine sexes, male and female *C. gariepinus.* These K-values may be attributed to feeding of the fishes to satiation. This results indicated that the experimental fish were in good condition of health in the IBC tank. The Fulton Condition Factor determined in this study ranged from 0.922 to 1,074 (Fig 10 and 11). Relative Condition ranged from 0.905 to 1.086 (Figure 7, 8 and Table 4). Condition factor of 0.905 to 1.086 indicate good health condition of the fish.

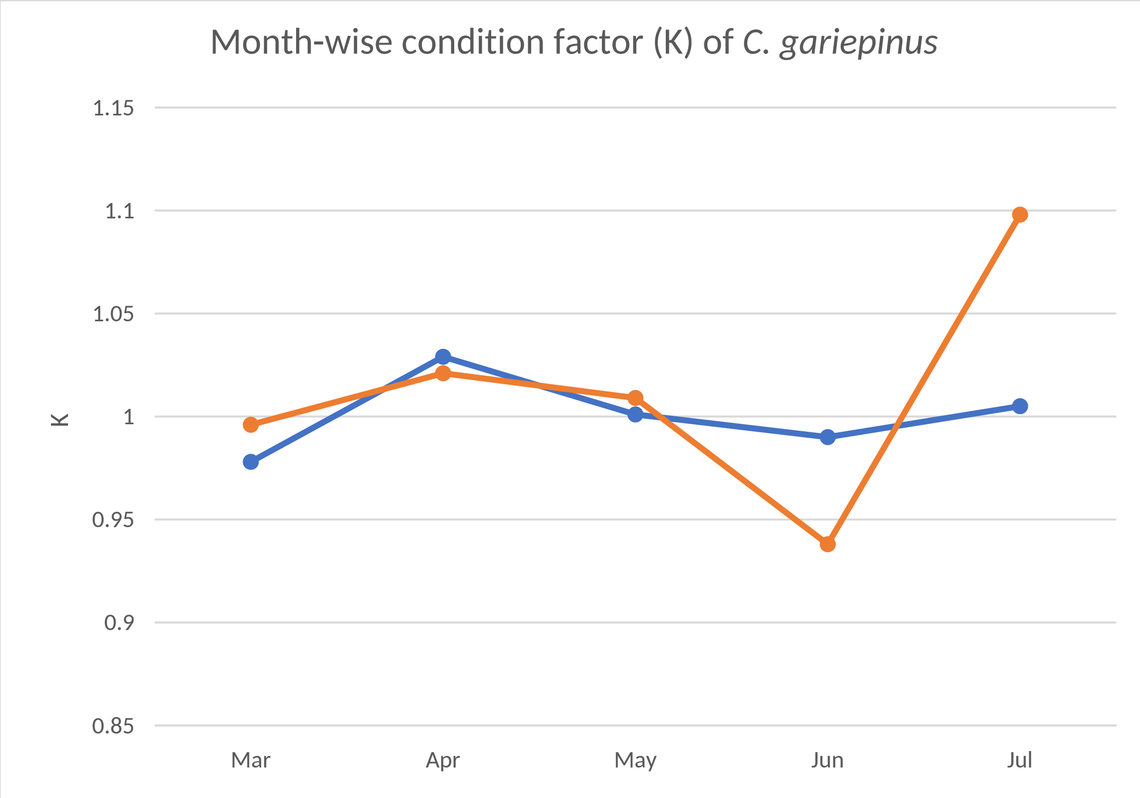

Figure 4.7. Month-wise condition factor (k) of *C. gariepinus*

Table 4.4 Monthly mean length-weight and condition factor of male and female *C. gariepinus* in the LL.

MALES				FEMALES		
Months	**Length (cm)**	**Weight (g)**	**K**	**Length (cm)**	**Weight (g)**	K
March	9.85±0.65	31.55±1.95	0.9894	10.05±0.45	31.4±0.700	
April	10.519±0.639	36.507±9.807	0.9995	10.145±0.905	32.169±9.228	
May	13.831±0.985	80.950±17.221	1.0558	12.759±0.580	65.064±12.064	
June	19.392±1.652	203.745±42.381	0.9920	17.174±1.498	153.32±34.738	
July	23.870±0.108	336.722±27.868	1.0076	18.613±0.284	205.218±22.706	

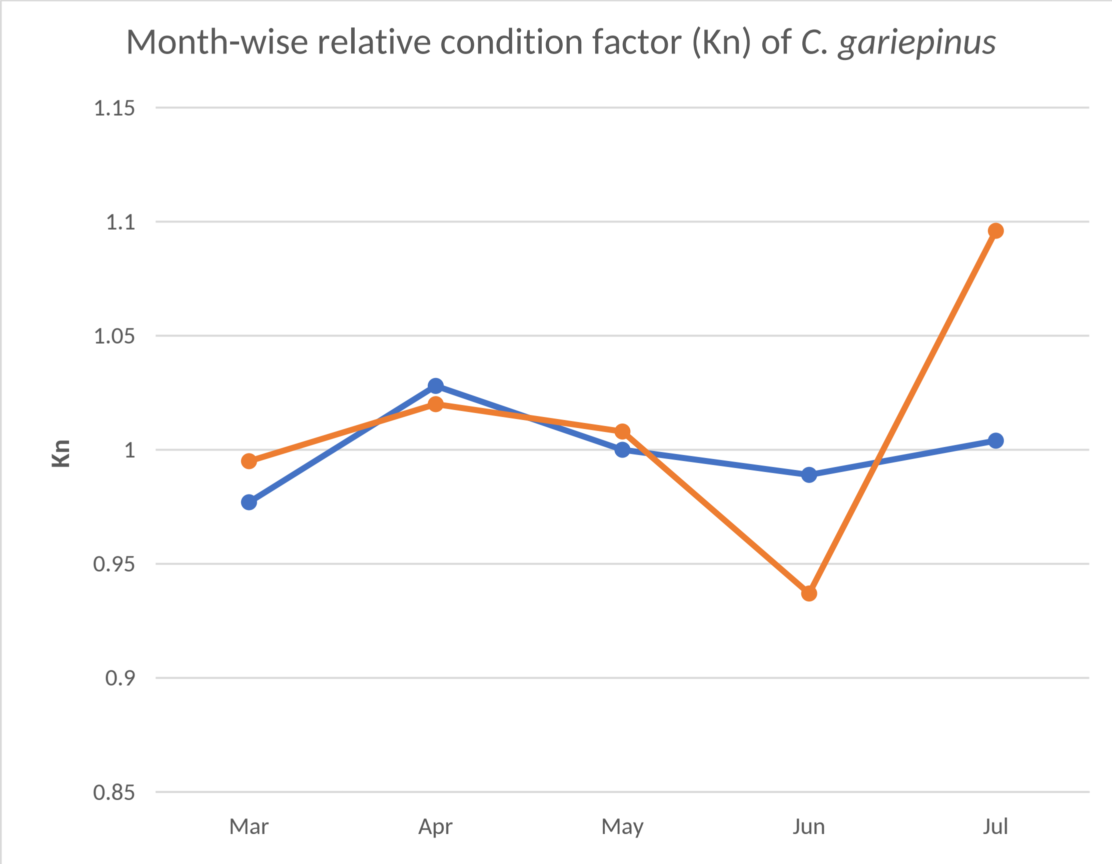

Figure 4.8. Month-wise relative condition factor (Kn) of *C. gariepinus*

Table 4.5. The three (3) Important Condition factors for fish health state

Categories	**Fulton Condition Factor (K) (Fulton, 1911)**	**Modified Condition Factor (Ricker, 1975)**	**Relative Condition Factor (Kn) (Le Cren 1951)**
Mean	1.008	1.128	1.00
Minimum	0.922	1.013	0.905
Maximum	1.074	1.216	1.086

4.1.2.1 Sex Ratio of Experimental Fish

The sex ratio of the fish was 52.5% (21) for male and 47.5% (19) for the female (47.5%). This accounted for a sex ratio of 1.42:1.58 (Female:Male). There was no significant difference ($p>0.05$) in the sex ratio observed thus validating the hypothesis (Table 4.6).

Table 4.6 Chi square test on sex ratio of *C. gariepinus*

Sex	Observed (Oi)	Expected (Ei)	O-E	$(O-E)^2$	$(O-E)^2$ /E
Male	21	20	-1	1	0.05
Female	19	20	1	1	0.05
Total					0.10

4.1.3 Objective 3

- Assess water quality variables in the aquaponics system throughout the culture period.

Hypothesis

- H_O: "Water quality of the culture medium is good and within recommended range for the culture of *C. gariepinus.*"
- H_a: "Water quality of the culture medium is not suitable for the culture of *C. gariepinus*."

Table 4.7. Mean values of water quality parameters

Parameter	Mean value	Standard Deviation(STD)
Dissolves Oxygen (DO)	7.29	1.8
Temperature	29.11	3.557
pH	7.1	0.587
Ammonia (NH3)	0.037	0.009
Nitrate (NO3)	0.032	0.011
Nitrite (N02)	0.017	0.007
Electrical Conductivity	1133.6	0.007
Total Dissolved Solid (STD)	233.1	127.275
Phosphate (PO4)	0.023	0.028

Alkalinity (KH)	27.9	6.540
Salt	0.241	0.025

4.2 Discussion

The results obtained in the study has clearly indicated that the NFT aquaponics systems of the INCiTiS living laboratory at the Department of Aquaculture and Fisheries Management, Njala University effectively supported the culture of the African catfish (*C. gariepinus*).

The results of length-weight relationship of catfish species *Clarias gariepinus* obtained from Jibia Reservoir revealed allometric pattern of growth. The combined b value obtained in this study is 2.8759, while the values for the male and female fish are 2.7649 and 3.0393 respectively. So many factors such as season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions (Bagenal and Tesch, 1978; Froese, 2006) affects fish weight and growth pattern. The differences in the values of "b" can be ascribed to one or a combination of the factors. These may include the number of specimens examined, area and season effects and distinctions in the observed length ranges of the specimens and culture period (Moutopoulos and Stregiou, 2002). The correlation coefficient "r" for males, females and combined sexes were 0.988, 0.994 and 0.996 respectively. The b value of the female which is higher than that of the male is in consonance with the result obtained by Anyanwu et al. (2007) who reported higher value for female *C. gariepinus*. It is important to point out that the b-value of 3.0393 obtained for the female experimental fish was near isometric growth, which indicated that the female fish grow better than the male. This shows that the female *C. gariepinus* was in a better condition than the male; this could be as a result of better opportunity to availability of food. Isometric growth is connected with no change of body shape as an organism grows ($b = 3$). Negative allometric growth indicates the fish becomes slender as it increases in weight ($b < 3$) (Suleiman et al., 2017).

The K values of 1.002, 1.005 and 1.008 obtained for combine sexes, male and female *C. gariepinus* in this study were greater than 1, which indicate that the fish species' wellbeing in the aquaponics systems was satisfactory. According to Deekae et al. (2010) several factors affect the condition factor of fishes. The CF obtained in this study is not different from the results of Anyanwu et al. (2007), Davies et al. (2013), Olapade and Conteh (2019) and Oyebola et al. (2022). The overall mean condition factor obtained in this study are above the results from other studies. Fafioye and Oluajo (2005) reported condition factor of 0.79±0.15 for *C. gariepinus* in Epe Lagoon, while Anyanwu et al. (2007) recorded K value of 0.654±0.1907 for *C. gariepinus* in recirculation system.

The sex ratio of the of 1.42:1.58 (Female:Male) obtained in this study corroborated the result of the condition factor; the female catfish appears to compete favourably in the system, with less mortality. It is not common to have a quite close sex ration. Sex ratio in culture system or growth environment will be significantly affected by the rate of mortality which is also influenced by other factors.

The results obtained for water quality in this study as presented in Table 4.7 clearly shows that the aquaponics system functioned efficiently, as the parameters were all within the threshold recommended for the culture of tropical fish species. Water quality monitoring is important in the fish tank. The survival and growth of the fish depends on the range of water quality variables. The water quality parameters measured in this study as shown are within the recommend range for tropical fish culture. The DO, pH and Temperature measured are critical for the survival of fish and growth of vegetables in the aquaponics. The parameters are Safe for fish survival and growth, and provides the nutrient needs of the vegetables grown in the NFT pipes.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The current study revealed that C. gariepinus in aquaponics system at Njala University INCiTiS living laboratory exhibited both positive and negative allometric growth pattern with a strong positive correlation between the total length and weight of the species. It can currently be decided that the species are in better physiological state of well-being with greater than 1 condition factor. The results further showed that *C. gariepinus* can be successfully cultured in aquaponics system of fish and vegetable.

5.2 Recommendation

The following recommendations are made based on the results obtained in this study.

i. The researcher would like to recommend that additional aeration facility be provided in the aquaponics, as this is believed to better improve fish survival and growth, and also at the same time improve the growth of crops in the system.

ii. The researcher would like to recommend the prompt removal of sludge, leftover feed in the system, as this has the capacity to deteriorate water quality and consequently affecting the health and survival of the fish.

iii. There is need to carry out studies on the relationship between fish growth, condition factor and stocking density in the aquaponics system.

Acknowledgement

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REFERENCES

Abobi, S.M. (2015).Weight–length models and relative condition factors of nine freshwater fish species from the Yapei stretch of the White Volta, Ghana.Elixir Appl. Zool. 79:30427–30431.

Afolabi, O. J., Olususi, F. C., & Odeyemi, O. O. (2020). Comparative study of African catfish parasites from cultured and natural habitats. *Bulletin of the National Research Centre*, *44*(1), 163. https://doi.org/10.1186/s42269-020-00419-4.

Anyanwu, P.E., Okoro, B.C., Anyanwu, A.O. and Matanmi, M.A. (2007). Length – weight relationship, condition factor and sex ratio of African mud catfish (Clarisa gariepinus) reared in indoor water recirculation system tanks. Research Journal of Biological Science, 2(7): 780 - 783.

Ayo-Olalusi, C. I. (2014). Length-weight Relationship, Condition Factor and Sex Ratio of African Mud Catfish (Clarias gariepinus) Reared in Flow-through System Tanks. *Journal of Fisheries and Aquatic Science*, *9*(5), 430–434. https://doi.org/10.3923/jfas.2014.430.434

Baßmann, B., Brenner, M., & Palm, H. W. (2017). Stress and Welfare of African Catfish (Clarias gariepinus Burchell, 1822) in a Coupled Aquaponic System. *Water*, *9*(7), Article 7. https://doi.org/10.3390/w9070504

Bagenal, T. and Tesch, F. W. 1978. Age and growth, In: Bagenal, T. (Ed.), Methods for assessment of fish production in freshwater, Handbook 3. Blackwell Scientific Publications, Oxford, UK, p. 101-136.

Barbu M., Ceanga E. and Caraman S., (2016) Water quality modelling and control in recirculating aquaculture system; Intech Open Limited, The Shad 25th Floor, 32 London Bridge Street, London, SE1 9SG, United Kingdom. 53pp. DIO: 10.5772/63202.

Barrie A., Swaray A., Barrie M., and Beah J. (2021). Evaluating Drinking Water Treatment Methods in the Njala University and Neighboring Mokonde Communities in Southern Sierra Leone. Natural Resources > Vol.12 No.8. DOI: 10.4236/nr.2021.128019

Belão, T. C., Leite, C. a. C., Florindo, L. H., Kalinin, A. L., & Rantin, F. T. (2011). Cardiorespiratory responses to hypoxia in the African catfish, Clarias gariepinus (Burchell 1822), an air-breathing fish. *Journal of Comparative Physiology. B,* *Biochemical, Systemic, and Environmental Physiology*, *181*(7), 905–916. https://doi.org/10.1007/s00360-011-0577-z

Dadebo, E. 2000. Reproductive biology and feeding habits of the catfish *Clarias gariepinus* (Burchell) (Pisces: Clariidae) in Lake Awassa, Ethiopia. SINET: Ethiopian Journal of Science, 23(2), 231-246.

Davies, O. A., Tawari, C. C., & Kwen, K.-I. (2013). Length –Weight Relationship, Condition Factor and Sex Ratio of Clarias gariepinus Juveniles Reared in Concrete Tanks. *International Journal of Scientific Research in Environmental Sciences*, 324–329. https://doi.org/10.12983/ijsres-2013-p324-329

Deekae SN, Chukwu KO, Awotogha G (2010). Length –Weight relationship and condition factor of Alestis alexandrius (Geoffrey SaintHillarie 1817) in Bonny River, Nigeria. Journal of Agricultural Research and Policies, 5(4): 16- 18.

Dikou, A. (2023). Weight–length relationship in fish populations reflects environmental regulation on growth. *Hydrobiologia*, *850*(2), 335–346. https://doi.org/10.1007/s10750-022-05072-8

Din, W. N. S., Endut, A., Lananan, F., & Kasan, N. (2024). Performance Evaluation of Gravel and Clay Pebbles Growth Beds in Aquaponics for Okra (Abelmoscus esculentus) and Catfish (Clarias gariepinus) Growth and Production. *Environment and Ecology Research*, *12*, 140–153. https://doi.org/10.13189/eer.2024.120205

Egbal et al., (2011) -

Ekawati W.A., Ulfa M.S., Yanuar T.A. and Kumiawan A. (2011) Analysis of aquaponic-recirculation aquaculture system (A- Ras) application in the catfish (Clarias gariepinus) aquaculture in Indonesia. Aquaculture Studies, 21, 93- 100. http://doi.org/10.4194/2618-6381-v21_3_01.

Endut, A., Jusoh, A., Ali, N., Wan Nik, W. B., & Hassan, A. (2010). A study on the optimal hydraulic loading rate and plant ratios in recirculation aquaponic system. Bioresource Technology, 101(5), 1511-1517.

Espinal C.A and Mutalic D., (2019) Recirculating aquaculture technologies: Aquaponic Food Production System; pp. 35-77. https://doi.org/10.1007/978-3-15943-6_3.

Fafioye, O.O. and Oluajo, O.O. (2005). Length - weight relationship of five fish species in Epe Lagoon, Nigeria. African Journal of Biotechnology, 4: 749 – 751.

Fagbuaro, O., desola majolagbe, Ola-oladimeji, Ekundare, O., Adebayo, C., & Akinyemi, O. (2019). Length—Weight Relationship and Condition Factor of Clarias gariepinus from Igbokoda, Ondo State, Nigeria. *Journal of Zoological Research*, *3*, 15–18. https://doi.org/10.22259/2637-5575.0302004

Felix, A. I., Robert, U. O., Christopher, C. E., Christian, U., and Christiana, O. I. (2018).Economic of small holder fish farming to poverty alleviation in the Niger Delta region of Nigeria. Turkish Journal of Fisheries & Aquatic Sciences. 19(4), 313–329.

Fishbase. (2013).Online fish identification sheet. Available at http://www.fishbase.org/search. php, accessed on 10/06/2013.

FOA, European Union, & CIRAD. (2022). FOOD SYSTEMS PROFILE - SIERRA LEONE Catalysing the sustainable and inclusive transformation of food systems. *Food and Agriculture Organization of the United Nations, the French Agricultural Research Centre for International Development, and the European Union*. https://openknowledge.fao.org/server/api/core/bitstreams/031f61b5-fa96-4f8d-ae90-99ff734aa0a0/content

Froese, R. (2006). Cube law, condition factor and weight-length relationships: history, metaanalysis and recommendations. Journal of applied ichthyology 22(4):241-251.

Goddek S, Joyce A, Kotzen B, and Dos-Santos M (2019). Aquaponics and Global Food Challenges. In: Goddek, S., Joyce, A., Kotzen, B., Burnell, G.M. (eds) Aquaponics Food Production Systems. *Springer, Cham*. https://doi.org/10.1007/978-3-030-15943- 6_1.

Hadiza, Y. B., Sadauki, M. A., Nababa, A. S., & Abubakar, I. (2023). LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF CLARIAS GARIEPINUS (BURCHELL, 1822) IN JIBIA LOCAL GOVERNMENT AREA, KATSINA STATE, NIGERIA. *Nigerian Journal of Animal Production*, 13–16.

Haruna, A. B., & Bichi, A. H. (2017). Length-Weight Relationship and Condition Factor of *Clarias gariepinus* (Burchell, 1822) Cultured in Earthen Ponds. Bayero Journal of Pure and Applied Sciences, 10(1), 473-478.

Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Jasmine, S., Oscoz, J., Miranda, R., & Ohtomi, J. (2006). Condition, length–weight and length–length relationships of the silver catfish Mystus vittatus (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. Journal of Applied Ichthyology, 22(4), 304-307.

Htun-Han M (1978). The reproductive biology of the dab *Limanda limanada* (L.) in the North Sea: gonadosomatic index, hepatosomatic index and condition factor. J Fish Biol 13(1):351–377

Huntington T., Avarre J.C., Focken U., Osward M., Pucher J. and Sorgeloos P., (2017) Opportunities and challenges for aquaculture in developing countries; Joint Report by; Agence Francaise De Development (AFD), European Commission (EC) and Deutsche Gesellschaft for Internationale Zusammenarbeit (GIZ) https://ec.europeaid/fisheries- and-aquacultureeuropean-development-cooperation-state-play-2015en.

Kim H. J., (2018) Aquaponics Basics: Horticulture and landscape architecture; Purdue University, Department of agriculture, pp. 6

Konan, K.J, Eyi,A.J, N'Da, K and Atsé,B.C(2017).Length-weight relationship and condition factor for 18 fish species from Ono, Kodjoboué and Hébé lagoons, Southeast of Ivory Coast. International Journal of Fisheries and Aquatic Studies 2017; 5(6): 13-18

Langi, S., Maulu, S., Hasimuna, O., Kapula, V., & Tjipute, M. (2024). Nutritional requirements and effect of culture conditions on the performance of the African catfish (Clarias gariepinus): A review. *Cogent Food & Agriculture*, *10*, 2302642. https://doi.org/10.1080/23311932.2024.2302642

Le Cren E.D. (1951). The length- weight relationship and seasonal cycle in gonadal weight and condition in the perch (Perca fluviatilis). Journal of Animal Ecology, 20: 201–219. https: //org/10. 2307/1540.

Li, Y., Feng, M., Huang, L., Zhang, P., Wang, H., Zhang, J., Tian, Y., & Xu, J. (2023). Weight–Length Relationship Analysis Revealing the Impacts of Multiple Factors on Body Shape of Fish in China. *Fishes*, *8*(5), Article 5. https://doi.org/10.3390/fishes8050269

Maranga, B., Kagali, R., Omolo, M., & Sagwe, P. (2023). *Effect of growth substrates on water quality, catfish (Clarias gariepinus) culture and spinach (Spinacia oleracea) propagation under aquaponic system*. *34*, html.

Mon, Ei Ei Swe, T, Zin,P.P and Dwe,K.L (2020). Length-weight relationship, condition factor and sex ratio of tade mullet (Liza tade Forsskal, 1775) from Mawlamyine, Mon state, Myanmar. Journal of Aquaculture & Marine Biology. 2020;9(4):107–112.

Moutopoulos DK, and Stregiou KI (2002). Length-Weight and Length-Length relationships of fish species from the Aegean Sea (Greece), *Journal of Applied Ichthyology*, 18: 200-203.

Muhammad, A. Y., Taofik, A. B., 2Babangida, A., and Salim, A. M. (2020). length-weight relationship, condition factor and growth of alestes baremose (joaniss, 1835) in zobe dam, 16 katsina.FUDMA Journal of Sciences (FJS)ISSN online: 2616-1370ISSN print: 2645 -2944Vol. 4 No. 1, March,2020, pp 24 –28.

Nóbrega, F., Dumith, M. T., Salgueiro, F., & Santos, A. F. G. N. (2024). Genetic origin and morphometric traits of invasive African catfish (*Clarias gariepinus*) in a protected area in southeastern Brazil. *Environmental Biology of Fishes*, *107*(3), 369–380. https://doi.org/10.1007/s10641-024-01536-z

Nyamweya, C. S., Mlewa, C. M., Ngugi, C. C., & Kaunda-Arara, B. 2010. Validation of daily growth of African catfish *Clarias gariepinus* (Burchell 1822) young-of-the-year from Lake Baringo, Kenya. Lakes and Reservoirs: Research and Management, 15, 341–345.

Ogamba, E. N, Abowei J. F.N, Onugu A. (2014) Length–weight relationship and condition factor of selected finfish species from Odi River, Niger Delta, Nigeria. J Aquat Sci.; 29 (1):1–12.

Omondi, J.G; Gichuri, W.M and Veverica, K. (2001) A partial economic analysis for Nile tilapia (Oreochromis niloticus) and sharp toothed African catfish (Clarias gariepinus) polyculture in central Kenya. Blackwell journal of Aquaculture Research Vol 32: pp. 693-700

Olanrewaju, G. O., Sarpong, D. D., Aremu, A. O., & Ade-Ademilua, E. O. (2022). *Growth performance and nutritional composition of Clarias gariepinus in flood-and-drain aquaponics coupled with three species of leafy vegetable* (p. 2022.10.06.511190). bioRxiv. https://doi.org/10.1101/2022.10.06.511190

Olapade OJ (2009). Effect of stocking density on water quality, survival and growth performance of the African Catfish (*Clarias gariepinus* Burchell 1882) cultured in earthen ponds. *Nigerian Journals of Fisheries* Vol. 6(1 & 2): 1 – 8

Olapade OJ and Conteh KU (2019). Growth Performance, Length – Weight Relationship and Condition Factor of *Clarias gariepinus* (Burchell 1822) Fed Graded Level of *Anisophyllea laurina* R. Br. Ex. Sabine Seed Meal (Monkey Plum). *J. Appl. Sc i. Envir on. Manage*. Vol. 23 (3) 505-511.

Olapade OJ and Quinn PG (2019). Nutritional Evaluation of Defatted Groundnut Cake meal with Amino acid as Protein Supplement in African Catfish (*Clarias gariepinus* Burch ell, 822) Juveniles Diet. *J. Fish. Aquat. Sci*., 1(1): 7- 14. ISSN 1816-4927; DOI:10.3923/jfas.2019.7.14.

Oyebola OO, Omitoyin SB, Hounhoedo AOO, and Agadjihouèdé H (2022). Length-weight relationship and condition factor revealed possibility of mix strains in *Clarias gariepinus* population of Oueme Valley, Benin Republic (West Africa). *Total Environment Research Themes*, 3-4. journal homepage:doi.org/10.1016/j.totert.2022.100009.

Palm, H. W., Berchtold, E., Gille, B., Knaus, U., Wenzel, L. C., & Baßmann, B. (2022). Growth and Welfare of African Catfish (*Clarias gariepinus* Burchell, 1822) under Dietary Supplementation with Mixed-Layer Clay Mineral Montmorillonite-Illite/Muscovite in Commercial Aquaculture. *Aquaculture Journal*, *2*(3), Article 3. https://doi.org/10.3390/aquacj2030013

Pauly, D., (1983). Some simple methods for the assessment of tropical fish stocks. FAO Fisheries

Rurangwa E. and Verdegem M.C.J., (2014) Micro-organisms in recirculating aquaculture systems and their management, Reviews in Aquaculture, INASP KENYAKaratina university College; https//doi.org/10.1111/raq.12057.

Safran P., (2009) Fisheries and Aquaculture; Fishing in the tropics, Philippine council for aquatic and marine research and development, Los Banos Laguna, Philippines Vol IV pp. 134-154.

Schram, E., Roques, J. A. C., Abbink, W., Yokohama, Y., Spanings, T., de Vries, P., Bierman, S., van de Vis, H., & Flik, G. (2014). The impact of elevated water nitrate concentration on physiology, growth and feed intake of African catfish *Clarias gariepinus* (Burchell 1822). *Aquaculture Research*, *45*(9), 1499–1511. https://doi.org/10.1111/are.12098

Shittu, A. I., & Oguntoye, V. (2020). Length-Weight Relationship and Condition Factor of Reared *Clarias Gariepinus* in Ilaro, Ogun State, Nigeria. *International Journal of Research and Scientific Innovation*, *7*(12), 174–176.

Somerville C., Cohen M., Pantanella E., Stankus A. and Lovatelli A., (2014) Small-scale aquaponics food production system; integrated fish and plant farming; FAO Fisheries and Aquaculture Technical Paper 589.

Suleiman, I. O., Akpa, G.N., Kabir, M. and Bolorunduro, P. I., (2017).Length-weight relationship and condition factor of Clariid fish species in Kano Rivers, Kano State, Nigeria.Nig. J. Anim. Prod. 2017, 44(3):135 -139 Nigerian Society for Animal Production/

Tolulope, A. (2014). Seasonal variation and Length-weight relationship of Clarias gariepinus from Oluwa River, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *8*, 51–59. https://doi.org/10.9790/2402-08715159

van de Nieuwegiessen, P. G., Olwo, J., Khong, S., Verreth, J. A. J., & Schrama, J. W. (2009). Effects of age and stocking density on the welfare of African catfish, *Clarias gariepinus* Burchell. *Aquaculture*, *288*(1), 69–75. https://doi.org/10.1016/j.aquaculture.2008.11.009

Wang, L., Wu, Z., Liu, M., Liu, W., Zhao, W., Liu, H., Zhang, P., & You, F. (2017). Length- weight, length-length relationships, and condition factors of black rockfish Sebastes schlegelii Hilgendorf, 1880 in Lidao Bay, China. *Thalassas: An International Journal of Marine Sciences*, *33*(1), 57–63. https://doi.org/10.1007/s41208-017-0021-6

APPENDIX

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.998020094
R Square	0.996044109
Adjusted R Square	0.995549623
Standard Error	0.029126904
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.70888524	1.70888524	2014.3	6.7069E-11
Residual	8	0.006787013	0.000848377		
Total	9	1.715672252			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.948055883	0.094162656	-20.68820025	3.12E-08	-2.16519536	-1.730916409
log of length	2.875922604	0.064078904	44.88095791	6.71E-11	2.72815639	3.023688822

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.993813
R Square	0.987664
Adjusted R Square	0.985901
Standard Error	0.047051
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.240662634	1.240662634	560.4293	6.1E-08
Residual	7	0.015496404	0.002213772		
Total	8	1.256159038			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*

Intercept	-1.26493	0.142775517	-8.85955971	4.72E-05	-1.60254	-0.92732
log of length	2.76489	0.116793178	23.67338747	6.1E-08	2.488718	3.041062

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.997217
R Square	0.994442
Adjusted R Square	0.993648
Standard Error	0.027495
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.946885	0.946885	1252.536	3.73E-09
Residual	7	0.005292	0.000756		
Total	8	0.952177			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.56186	0.100222	-15.5839	1.08E-06	-1.79884	-1.32487
log of length	3.039343	0.085879	35.39118	3.73E-09	2.836272	3.242413