COMPARISON OF GROWTH AND MOULTING FREQUENCY OF SCYLLA SERRATA IN A FLOW THROUGH VERTICAL SYSTEM AND IN RACEWAYS.

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Table of Contents

List of figures 3

List of tables 4

Acknowledgement 5

Executive Summary 6

Abstract 8

Introduction 9

Materials and Methods 10

Collection and transportation of S. serrata 10

Experimental system 11

Feeding 13

Specific growth rate (SGR) weight and width 13

Total molting frequency. 14

Feed conversion ratio (FCR) 14

Statistical analysis 14

Results 15

Growth and survival 15

Mud crab growth model. 18

Discussion 20

Conclusion and recommendations 22

References 23

List of figures

Figure 1:Collection of S. serrata from a mangrove forest. 10
Figure 2: Vertical mud crab system. 12
Figure 3: Lug box that was placed in the crab raceway. 12
Figure 4. The graphs display the mortality rates (%) for two different systems, highlighting the effectiveness of each approach for culturing S. serrata. The x-axis represents the systems, and the y-axis shows the corresponding mortality rates. 16
Figure 5. The graph illustrates average specific growth rate (%) for the weight of S. serrata in the land-based raceway and vertical system. The data highlights the variations in growth rates among the different systems. 17
Figure 6. The graph illustrates average specific growth rate (%) for the width of S. serrata in the land-based raceway and vertical system. The data highlights the variations in growth rates among the different systems. 17

List of tables

Table 1. Mean nutrient level- Nitrate-N, Nitrite-N, Total Ammonia-N and Phosphorus with standard deviation at the end of the 123 days experiment in the land-based raceway and vertical system 14

Table 2. Mean molting frequency and FCR of S. serrata in land-based raceway and vertical system over a period of 123 days with standard deviation 20

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Executive Summary

Mud crabs are significant to fisheries due to their large size, high meat yield, and exquisite flavor, and holds substantial importance in inshore fisheries across many tropical and warm temperate regions. Overfishing has drastically reduced their populations, prompting aquaculture as a sustainable alternative. This study investigates the growth and molting frequency of the mud crab *Scylla serrata* in two different aquaculture systems: a flow-through vertical system and land-based raceways. The objective was to evaluate the survival rates, specific growth rates, feed conversion ratios, and molting frequency of *S. serrata* in both systems.

A total of 22 mud crabs were collected and allocated to either the vertical system or land-based raceways at the Seychelles Maritime Academy. Key parameters such as survival rates, specific growth rates, feed conversion ratios, and molting frequency were recorded over a period of 123 days. The vertical system demonstrated a significantly higher survival rate (83.33%) compared to the land-based raceways (25%). No significant differences were observed in the specific growth rates for weight or width between the two systems. The feed conversion ratio was significantly different, with the vertical system being less efficient. The vertical system's higher survival rate suggests it better mimics the natural habitat of *S. serrata*, potentially reducing stress levels associated with higher light exposure in raceways. Despite no significant differences in growth rates, the feed efficiency in the raceways was better, indicating room for optimization in the vertical system. The findings underscore the potential of vertical systems in enhancing survival rates while highlighting the need for improved feed management strategies in both systems to optimize growth performance and overall aquaculture efficiency.

The study concludes that while vertical systems offer higher survival rates for *S. serrata*, both aquaculture systems require further refinement in feed management to achieve optimal growth and efficiency. The vertical system, in particular, shows promise in creating conditions closer to the crabs' natural habitat, which could be beneficial for aquaculture practices in regions with limited space. Future research should focus on optimizing feed formulations and management practices to improve the feed conversion ratio in vertical systems. Additionally, exploring

variations in environmental conditions such as light exposure and water quality could provide further insights into maximizing the growth and survival of *S. serrata* in aquaculture settings.

Abstract

Scylla serrata, commonly known as the mud crab, belongs to the Portunidae family and is prevalent in tropical and warm temperate regions of the Indo Pacific area. Due to its large size, high meat yield, and excellent flavor, it holds significant importance for inshore fisheries in numerous countries. However, overfishing has led to a significant decline in its population. As a result, aquaculture has been considered as a sustainable solution to this problem. This study aimed to investigate the growth and molting frequency of *S. serrata* in two different aquaculture systems: a flow-through vertical system and land-based raceways. The study measured various parameters, including survival rates, specific growth rates, feed conversion ratios, and molting. The results indicated that the vertical system had a significantly higher survival rate compared to the raceway system ($p= 0.0004$). Although no significant differences were observed in the specific growth rate or molting between the two systems ($p <0.05$), the feed conversion ratio was significantly different between the two systems ($p= 0.0009$), with the FCR being less efficient in the vertical system. The higher survival rate in the vertical system suggests that it mimics the natural habitat of the crabs more closely. These findings imply that while the vertical system improves survival, both systems require further optimization in feed management and nutritional strategies to enhance growth performance and overall efficiency in mud crab aquaculture.

Introduction

Mud crabs, commonly referred to as *Scylla spp*., is a portunid crab (family: Portunidae) and are prevalent in tropical and warm temperate regions of the Indo Pacific area. These crustaceans are of great significance to inshore fisheries in numerous countries due to their large size, high meat yield, and exquisite flavor (Keenan, 1999; Le Vay, 2001; Marichamy & Rajapackiam, 2001). *S. serrata* plays a vital role as a top predator within the mangrove food web (Hill, 1994) and exhibits rapid growth, reaching 160mm carapace width (CW) in the first 15 months (Hill, 1975) and potentially reaching up to 280 mm CW at around 2-3 kg (Heasman, 1980), within a lifespan of 3-4 years (Alberts-Hubatsch et al., 2016). Adults typically reside in mangrove creeks and estuaries, where berried females migrate to release their larvae (Hill, 1994). Crabs can reach sexual maturity in as little as 12–18 months in tropical latitudes but can take as long as 24 months in more temperate locations (Hill 1994).

However, the extensive fishing of *S. serrata* over the long-term lead to a significant decrease in their population (Triyanto et al., 2012)., and aquaculture has been seen as a solution to this problem. Mangrove crab farming is considered to be profitable due to their fast growth rate and simple maintenance requirements, as well as their high market value (Dumas et al., 2012). The molting process is the means by which mangrove crabs grow, resulting in a softshell crab phase during the molting period. Softshell crabs have greater economic value than hard shell crabs, as all parts of the crab can be utilized (Karim, 2015). In Southeast Asia, *S. paramamosain* is successfully farmed with hatchery reared juveniles, while *S. serrata* is primarily used for the fattening of wild-caught juveniles in the Western Indian Ocean region, particularly in Madagascar, Kenya, and Tanzania.

One of the characteristics of crabs is cannibalism (Usman, et al., 2016) which means that if cultivated, you must use a separate container for each individual. The vertical crab hotel is a system that allow the intensification of mud crab production while allowing each crab a separate container preventing cannibalism. This greatly increases the number of crabs that can be cultivated per area and is ideal for regions where land is expensive.

As the aquaculture sector in Seychelles continues to grow, it is crucial to diversify the species and technologies used in production to ensure the provision of high-quality seafood products for the local market. Mud crab is one of the target species for aquaculture. The environmental conditions of Seychelles waters, such as temperature and salinity, are ideally suited to mud crab growth and survival. This study aims to compare two different systems—vertical system vs a land-based raceway—to see which one will result in higher productivity.

Materials and Methods

Collection and transportation of S. serrata

A total 24 *S. serrata* were collected starting from May 2023 to November 2023 from mangrove habitats around Mahé. Crab traps were set in the mangroves with bait inside and the next day the traps were removed. *S. serrata* with carapace width of 15cm or lower were brought back to the sea urchin research facility in a bucket whereas bigger crabs and other bycatch such as Northern mud gudgeon were removed from the traps and released back into the mangrove (Fig 1).

Figure 1:Collection of S. serrata from a mangrove forest.

Experimental system

The experiment took place at the sea urchin research facility (SURF), located at the Seychelles Maritime Academy, Providence. At the facility *S. serrata* were allocated to either raceway systems or crab boxes (Figure 2). At the beginning of the experiment, each *S. serrata* was weighed and measured for carapace length and width before being placed in labeled crab boxes or storage boxes. The sex of each crab was also recorded.

S. serrata were allocated to the crab boxes which measured 41cm x 32cm x 18cm (L x W x H. These boxes were stacked vertically, forming a vertical system, and received a continuous inflow of seawater (Figure 2). *S. serrata* in the raceway system were placed in storage boxes measuring 43cm x 32cm x 29cm (L x W x H) which had small holes pre-poked to allow good water flow (figure 3). These storage boxes were then placed in the raceway, where they also received a continuous inflow of seawater. The raceway was covered with shade cloth to reduce light exposure. It is to be noted that the facility is covered with a 50% shade cloth. Crabs were weighed and carapace length and width were measured using a vernier caliper when molting occurred (Mwaluma, 2014). Daily temperature in the raceway was 29.8 ± 0.6 °C and 30.0 ± 0.6 °C and DO was 5.7± 0.5mg/l in the raceway and 4.9 ± 0.6mg/l in the hotel and this was measured using a HQ portable meter. Salinity measured using a refractometer was an average 35ppt in both system and Ph measure by the low range Combo® pH and EC was an average of 7.9 in the raceway and 7.8 in the vertical system.

Figure 2: Vertical mud crab system.

Figure 3: Lug box in the crab raceway.

Feeding

S. serrata were fed at 10% of their individual body weight, every second day. The were fed bait fish which were purchased on local market or caught by aquaculture technicians. Remaining feeds were removed and weighed before adding new feed to be able to calculate consumption rate.

The parameters were calculated as follows:

Biological feed conversion ratio = feed consumed/weight gained

Economic feed conversion ratio = feed given/weight gained

The survival rates were examined based on Jobling (1995), where the survival rate was, was the total number of crabs in end of experiment minus the total number of crabs in beginning of experiment.

Survival (%) = 100 × (final number of crabs) / (initial number of crabs)

Specific growth rate (SGR) weight and width.

The body weight of S. serrata were measured once every month. The period of study was 123 days and therefore, there were five regular measurements body weight including the first and last measurements. The specific growth rate was calculated at the end of the study (De Silva & Anderson 1995) based on the data from the first and last measurement of BW. The formula for specific growth rate used was as following:

SGR (% per day)$\frac{W_2 - W_1}{t} \times 100\%$

The formula was based on De Silva & Anderson (1995), where SGR was the specific growth rate, W_1 was the initial weight, W_2 was the weight at the end of experiment, and t was the duration of the experiment. The same formula was used to measure the specific growth rate of width of S. serrata in each system, but width was measured only after molting.

Total molting frequency.

The evaluation on total molting frequency was done by calculating the total of molting that occurred based on the old exoskeleton in each system which was recorded daily within 123 days of experiment.

Feed conversion ratio (FCR)

The feed conversion ratio is a measure of an animal's efficiency in converting feed mass into increases in the crab mass. Specifically, the calculation of FCR is by obtaining the total weight of feed given divided by the weight gain (final weight minus starting weight) to obtain the feed conversion (USAID-Harvest, 2011). In this study the economical and biological FCR was assessed, whereby for the economical FCR the total weight of feed given was used to divide by the weight gained, and for the biological FCR was calculated by taking the total weight of feed eaten divided by the total weight gained.

The following environmental variables will be monitored daily (at the same time):

- Water temperature (°C)
- Dissolved oxygen (mg/L)
- Salinity (ppt).

Total Ammonia Nitrogen (TAN) (mg/L) using Palin test and pH was measured weekly.

Table 1. Mean nutrient level- Nitrate-N, Nitrite-N, Total Ammonia-N and Phosphorus with standard deviation at the end of the 123 days experiment in the land-based raceway and vertical system

	Nitrate-N	Nitrite-N	Total Ammonia-N	Phosphorus
Land-based raceway	10.15±8.18	0.04±0.03	1.47±1.02	0.27±0.21
Vertical system	9.45±7.15	0.04±0.03	3.22±3.60	0.22±020

Statistical analysis

Since the mud crabs had different starting weights, the data needed to be standardized to allow the construction of a growth model. The growth rate for the mud crab that had the lowest initial

weight was utilized to calculate the starting day for each of the crabs. This data was used to show growth over time and to construct a growth model.

Scikit-learn is a machine learning module that can be used to construct predictive mathematical models. All the growth data was entered into a csv file with the recorded weight at a specific day as the dependent variable and the day as the dependent variable. The weight data was Square Root transformed in order to establish linearity. Data was then split with 75 % of the data utilized to train the model and 25 % of the data used to test the model. Various statistics were calculated for this regression analysis. The model predictions were then plotted versus the actual record weights to visually demonstrate the validity of the model.

For comparing FCR and Growth rate between the two treatments the Shapiro-wilk test was applied to test normality and Levene's test to test for equal variances. Welch two-samples t-test was applied to calculate significant differences as there were unequal number of rows between the two treatments.

Results

Growth and survival

In assessing the survival rate of *S. serrata* between the two system- vertical system and land-based raceway with 12 mud crabs in each system, more than 80% of *S. serrata* died in the land-based raceway, while in the vertical system only 17% died (Figure 4). The results of the present study indicated that the survival rate of the mud crab juveniles was strongly affected by the types of shelter.

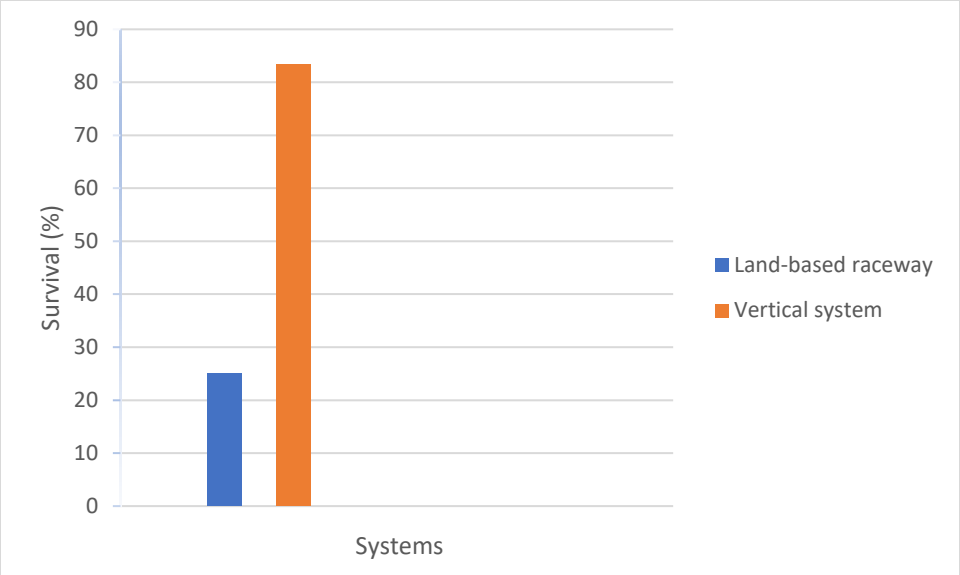

Figure 4. The graphs display the mortality rates (%) for two different systems, highlighting the effectiveness of each approach for culturing S. serrata. The x-axis represents the systems, and the y-axis shows the corresponding mortality rates.

Growth in *S. serrata* during the study were measured by weighing crabs monthly so to adjust feed accordingly. Furthermore, whenever, molting occurred *S. serrata* were weighed and carapace were measured. No significant differences were recorded for the specific growth rate for weight t (2.23) = 1.05, p= 0.39, and width t (3.38) = 2.44, p= 0.08 within the two system during the 123 days of the experiment. The highest average SGR weight (235.73±96.09) (Figure 5) and SGR width (54.88±9.57mm) (Figure 6) were both recorded in the land-based raceway S. *serrata* in the land-based raceway did have higher growth weight even if it was not significant. In this study, the highest and lowest growth in weight was recorded for the first 2 months were in the vertical system, with the highest gain being 145g and the lowest 4g. In the land-based raceway, the highest growth in the first two months was 49g. By the end of the 5-month study, only 3 crabs reached the marketable size of 400-500g, with two being in the vertical system at 463g and 417g, and the largest one from the land-based system at 473g. The largest crab gained a total of 293g during the 5 months in the system. The smallest crab at 5 months was from the land-based raceway, weighing 179.5g, but it started at the smallest weight of 54.5g.

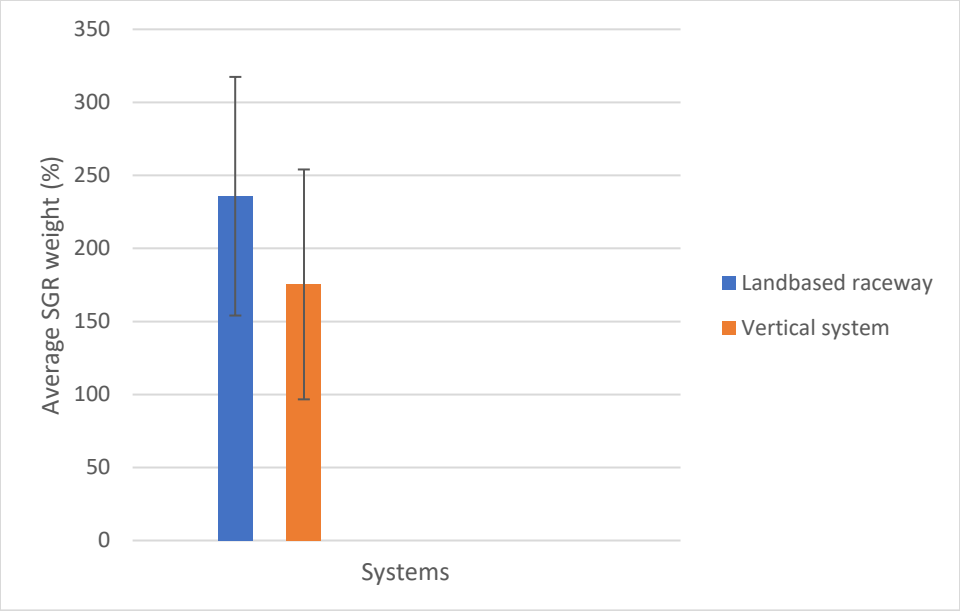

Figure 5. The graph illustrates average specific growth rate (%) for the weight of S. serrata in the land-based raceway and vertical system. The data highlights the variations in growth rates among the different systems.

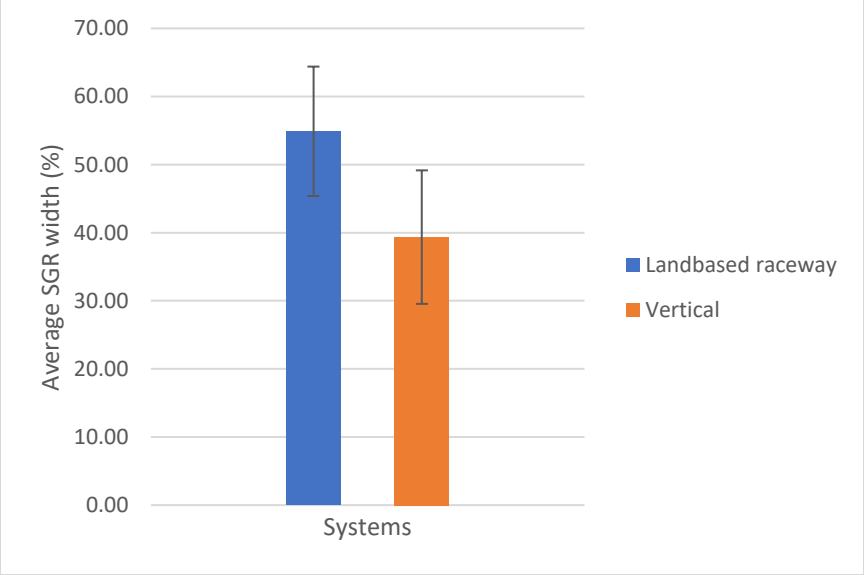

Figure 6. The graph illustrates average specific growth rate (%) for the width of S. serrata in the land-based raceway and vertical system. The data highlights the variations in growth rates among the different systems.

Mud crab growth model.

Figure 7 illustrates the predicted growth model for crabs, indicating that crabs can reach approximately 100 grams around the 100-day mark. This model is based on the relationship between the crabs' weight and the growth period. The curve shows a power curve, starting with a slower rate of weight increase that accelerates over time. This predicted growth curve captures the expected growth pattern of mud crabs. A graph was only constructed for the vertical system as the survival rate in the raceway system was low. In Figure 8, the scatter plot compares the actual growth data of mud crabs (black dots) with the values predicted by the growth model (yellow dots). The x-axis represents the number of days, ranging from 0 to approximately 250, while the y-axis represents the square root of the weight in grams. The graph demonstrates a strong alignment between the observed data and the model predictions. Both the observed data and model predictions follow a consistent upward trend, indicating that the model effectively captures the growth pattern of the mud crabs over time. Figure 9 presents the actual growth data of crabs in the vertical system, showing how the crabs' weight increases based on the model over approximately 250 days. Each color-coded dot represents the weight of a specific crab at various time points, with the x-axis indicating the number of days and the y-axis representing the weight in grams.

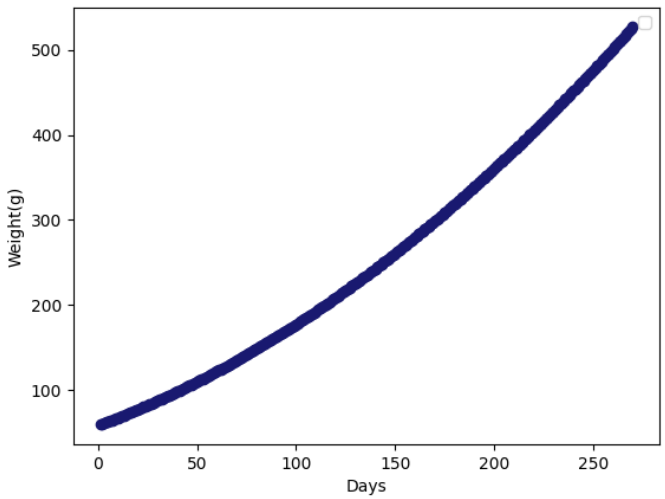

Figure 7. Mud crab growth rate predicted by the model.

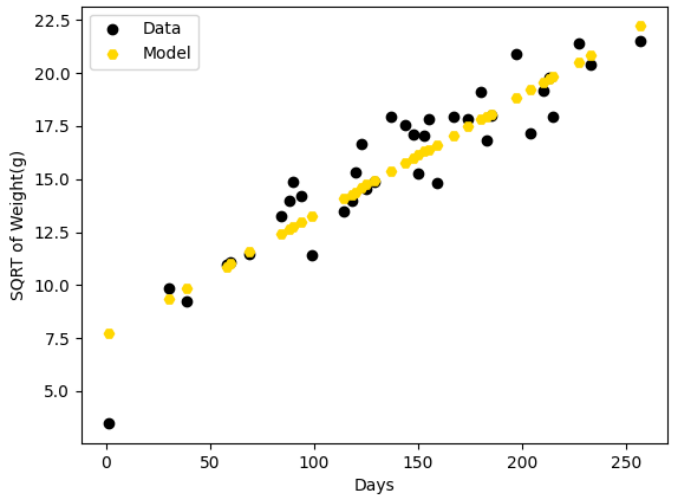

Figure 8. Mud crab growth data vs values predicted by the growth model. (m=0.05674; c=7.646, r2=0.915, mean square error= 1.059)

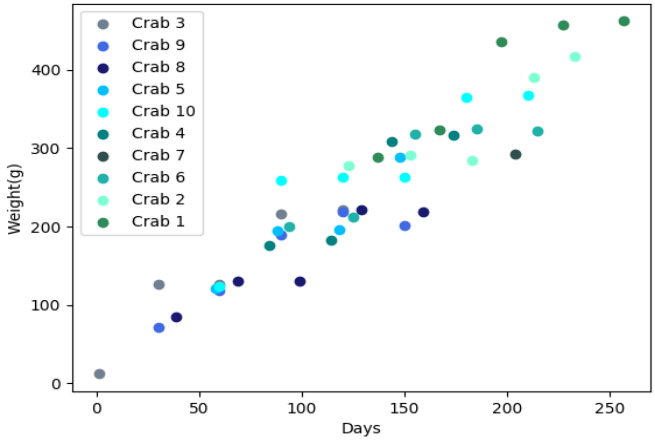

Figure 9. Growth of individual crabs in the crab hotel. Starting day was based on a growth model.

The molting frequency and FCR that occurred within 123 days was recorded and shown in Table 1. The economical and biological FCR was higher in the vertical system compared to the land-based raceway. However, the biological and ecological FCR are almost equal in each system individually. The molting frequency was also almost the same in the two systems. The Welch two sample t-test showed significant differences t (9.49) = 4.73, p= 0.0009 for FCR between the two

systems. No significant differences were recorded in the molting frequency between the two systems t(2.89)= 0.009, p= 0.93.

Table 2. Mean molting frequency and FCR of S. serrata in land-based raceway and vertical system over a period of 123 days with standard deviation

	Land-based raceway	Vertical system
Economical feed conversion ratio	5.24±0.34	10.88±3.71
Biological feed conversion ratio	5.23±0.34	10.88±3.71
Moulting frequency	1.33±0.57	1.30± 0.48

Discussion

The study aimed to compare the effectiveness of two different rearing systems, a land-based raceway, and a vertical system, for growth, and molting frequency of *S. serrata*. Initially, there were supposed to be 25 crabs in each system, however, there were challenges collecting juveniles, thus the experiment started with only 12 S. serrata in each. The size of the S. serrata in the system varied.

The study clearly demonstrated a huge difference in the survival rates of *S. serrata* between the land-based raceway and the vertical system. The vertical system exhibited a significantly higher survival rate of 83.33% compared to only 25% in the land-based raceway. The survival rate, however, does not seem to be associated with water quality as the results from nutrients analysis measured monthly showed that better water quality in the raceway compared to the vertical system as the level of ammonia was higher in the vertical system. The high level of mortality in the land-based raceway may have been caused by higher levels of stress within *S. serrata*. This stress could be attributed to exposure to higher levels of light, which is not typical of their natural habitat. Mud crabs usually reside in burrows in the intertidal zone in the wild, and the vertical

system provided a shelter area more closely related to their natural environment, which likely contributed to the lower mortality rate observed in this system.

Mud crabs can achieve a body weight of 60-100g within about 1-2 months (Quinitio & Parado-Estepa, 2017). At this size, they can be harvested for stocking to produce soft-shell crabs, a fast turnover product, or continue to be cultured for another 4-5 months in grow-out systems until they become adults and reach a marketable size of about 400-500g (Marichamy & Rajapackiam, 2001; Ganesh et al., 2015; Quinitio & Parado-Estepa, 2017). While the highest growth rate in the vertical system for the first 2 months 145g exceeded the typical range reported by Quinitio & Parado-Estepa (2017) 60-100g, the overall growth rates in this study show significant variability, The growth performance, measured by the average specific growth rates for both weight and width, showed no significant differences between the two systems. The p-values obtained from the Welch two-sample t-tests (weight: $p = 0.3908$, width: $p = 0.08201$) indicate that neither system provided a distinct advantage in terms of promoting the growth of *S. serrata*. This indicates that while the land-based raceway might support faster growth, it does not necessarily translate into overall better performance compared to the vertical system. The poorer water quality in the vertical system could be responsible for this difference and increasing the water flow could potentially increase the growth rate of the mud crabs in the vertical system.

The similar values for both economical and biological FCRs suggest consistent feed utilization across both systems. However, the overall FCR was higher in the vertical system, indicating that it was less efficient in terms of feed utilization compared to the land-based raceway. However, the higher consumption rate in the vertical system, double that of the land-based system also indicates that they may have stressed less in this system. This does suggest that crabs only need to be fed at 5 % body weight. Mud crabs require large quantities of trash fish to fulfill their protein requirements, leading to a high feed conversion ratio (FCR) (Dayal et al., 2019). From the results to be able to grow a crab from crablet to market size one will need to spend around SCR 400.00 in an aquaculture system at a FCR of 10.

Molting, in crabs is influenced by several factors, including environmental conditions like temperature, in this study the temperature was constant in the two system thus explaining why there were no significant differences in molting rates. In aquaculture, ensuring that mud crabs have access to environments that mimics their natural habitats, such as providing burrows or shaded areas, can significantly improve their overall health and growth rates.

Conclusion and recommendations

In this study, we compared the effectiveness of a land-based raceway and a vertical system for rearing *S. serrata*, focusing on survival rates, growth performance, and molting and feed conversion ratios. The vertical system demonstrated a higher survival rate, likely due to its provision of sheltered conditions similar to the crabs' natural habitat, reducing stress. Although the specific growth rates for weight and width showed no significant differences between the systems, the vertical system exhibited higher variability in growth and less efficient feed utilization, as indicated by a higher overall FCR. These findings suggest that while the vertical system improves survival, both systems require further optimization in feed management and nutritional strategies to enhance growth performance and overall efficiency in mud crab aquaculture. Finally, collecting from wild juveniles for aquaculture purposes is not advisable in Seychelles as the abundance of juvenile mud crabs is low. It is recommended that a hatchery is necessary for a profitable and sustainable *S. serrata* aquaculture business.

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