

The Impact of Environmental Factors on Sea Cucumber Growth in Unguja Ukuu and Fukuchani, Zanzibar

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Abstract

This study investigated the factors influencing the growth of sea cucumbers in specific locations in Zanzibar; Unguja Ukuu and Fukuchani. Data on oceanographic parameters, including sea surface salinity (SSS), Sea Surface Temperature (SST), and soil pH, were collected during both wet and dry seasons in Zanzibar. Soil samples were analyzed for nutrients including carbonate, particulate organic matter (POM), and chlorophyll, respectively. Statistical analysis was done using R-software in which *Pearson correlation*, *t-tests*, and *paired t-tests* were employed to assess the relationship between sea cucumber growth (weight and length) and environmental factors (more details in methods section). The study found that sea cucumbers in Fukuchani grew faster at the rate of 1.34 g/day than those in Unguja Ukuu at the rate of 1.28 g/day, similarly in lengths. The nutrient levels, particularly organic matter, significantly impact sea cucumber growth in the studied areas. For instance, Soil pH exhibited a positive correlation with both weight and length ($r = 0.6$ and 0.97 at $p \leq 0.05$) and length ($r = 0.6$ and 0.93) for both sites, while soil salinity (SSS) showed a strong positive correlation with weight but a weaker correlation with length. Similar case holds for Fukuchani where the correlation between the two parameters (SST and growth) was $r = -0.98$, and -0.96 at $p \leq 0.01$. Additionally, sea cucumber growth parameters were negatively correlated with SST in both locations. Chlorophyll was found to significantly influence sea cucumber development during the cold season, while carbonate and particulate organic matter were more influential during the wet season. Overall, the study indicated that oceanographic parameters and site-specific factors, such as nutrient availability, have a greater influence on sea cucumber growth as compared to weather parameters.

Keywords

Sea Cucumber, Sea Surface Salinity, Sea Surface Temperature, Carbonate, Chlorophyll

1. Introduction

This study aims to investigate the factors influencing the growth of sea cucumbers in specific locations in Zanzibar: namely, Unguja Ukuu and Fukuchani. The research explored the impact of environmental factors such as sea surface salinity, sea surface temperature, soil pH, and nutrient levels on sea cucumber growth. Additionally, the study examined the influence of weather patterns and intertidal zone development on sea cucumber growth. Understanding these factors is crucial for sustainable sea cucumber farming in the world, Tanzania, and Zanzibar in particular.

The declining global sea cucumber population has driven increased demand for imported sea cucumbers, including from Tanzania and Zanzibar. Sea cucumber or “Majongoo ya pwani,” cultivation, has become an important livelihood for coastal communities in Tanzania. Traditionally, sea cucumber fishing involved various demographic groups who processed the catch into a commercial product known as *beche de mer*. The processed sea cucumber product is then sold to Chinese agents along the coasts of Dar es Salaam, Tanga, Bagamoyo, Mafia, and Mtwara. The overall goal of this study was to contribute to the sustainable development of sea cucumber farming in Zanzibar by identifying optimal growth conditions and understanding the impact of their governing environmental factors.

2. Methodology

2.1. Study Area

The study was conducted in two specific locations in Zanzibar: Unguja Ukuu and Fukuchani, as shown in **Figure 1**. These sites were selected due to their proximity to the ocean, logistics, and their significance in sea cucumber farming. Zanzibar experiences a tropical climate with distinct wet and dry seasons. Unguja Ukuu is a coastal village in southern Unguja, which heavily relies on marine resources, including sea cucumber fishing. Fukuchani is a northern coastal village and is a KMKM camp which is actively involved in sea cucumber aquaculture.

2.2. Data Collection and Methods

The data to investigate the factors influencing sea cucumber growth in Unguja Ukuu and Fukuchani (in Zanzibar), which includes oceanographic parameters and soil nutrients, were collected over a five-month period from March 29 to August 06, 2023. Though the five-month period seems to be a small period to capture the full spectrum of the sea cucumber growth, since the time falls within

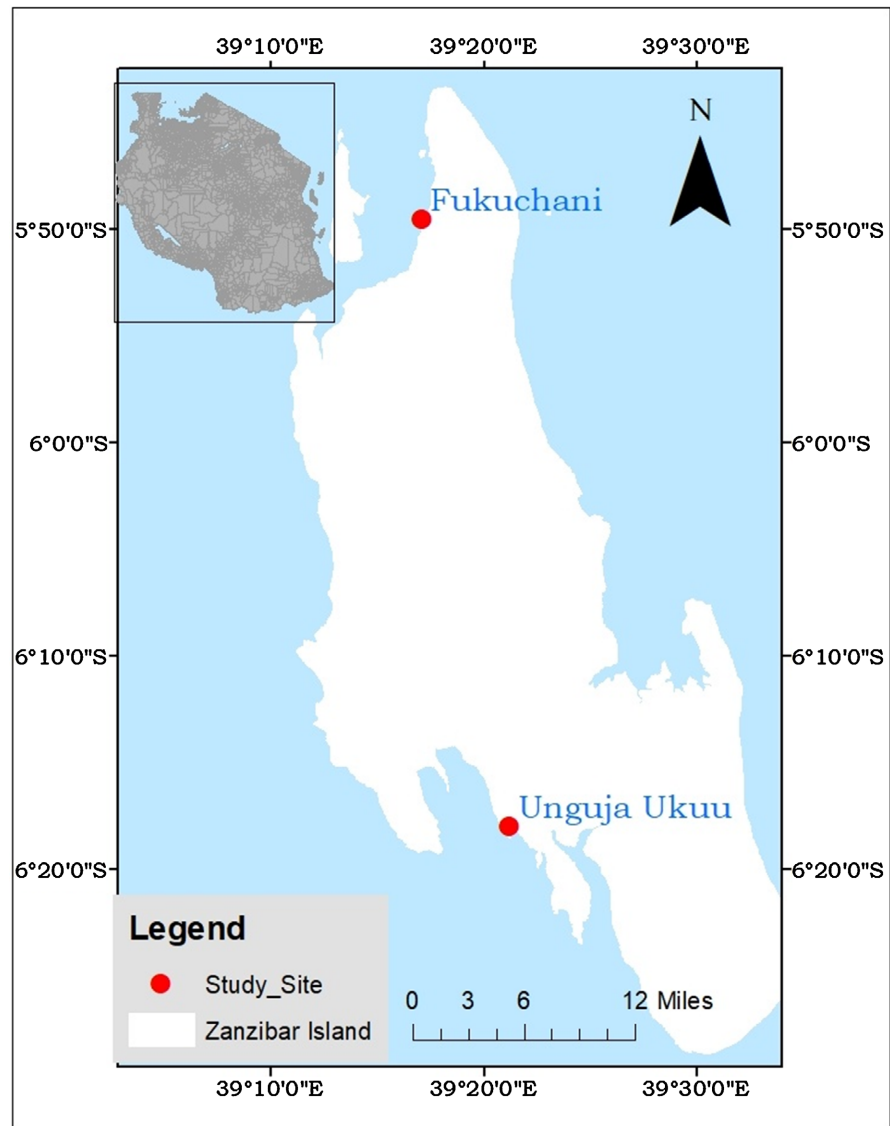


Figure 1. Study sites for Unguja Ukuu and Fukuchani in Zanzibar Island.

two seasons of wet (warm) and dry(cold) season the changes in their growth can be observed due to changes in nutrients and environmental condition including SST, SSS, pH among others. The main growth changes of weight and length were assessed by taking the measurements of the juvenile sea cucumber for every two-week interval and recording the measurements (weight and length and their differences (i.e., previous two weeks' record—the current two weeks' records)). The initial weights of the sea cucumber for Fukuchani range from 20 g to 40 g, while their lengths ranged from 8 cm to 11 cm. As for Unguja Ukuu, their weights ranged from 25 g to 60 g and their lengths ranged from 8 cm to 12 cm. These weights and lengths were estimated using the weighing scales and rulers. The oceanographic parameters, including sea surface temperature, salinity, and pH, were directly measured and recorded during field visits. Soil samples from the cages (which were 5 m × 7 m) where the sea cucumbers were raised were taken in two-time

intervals, before putting the juvenile sea cucumbers into the cage and during the last two weeks of the experiments. These samples were sent to the Institute of Marine Sciences (IMS) laboratory and analyzed for carbonate, organic matter, and chlorophyll content. The carbonate content was obtained as a weight loss from dried sand before and after being treated with acetone and then dried. Statistical analysis was done using *R-software* in which *Pearson correlation* analysis, student *t-tests* and paired *t-tests* were used to determine the relationships between these factors and sea cucumber growth (length and weight). The study aimed to understand the impact of environmental conditions on sea cucumber growth and identify optimal conditions for aquaculture.

3. Result and Discussion

3.1. The Variability of Oceanographic Factors (i.e., SST, SSS and pH)

The results in **Figure 2** which show the five months' variability of the oceanographic parameters (SST, SSS and water pH) over Fukuchani demonstrate that, during the observation period (March 29 to August 06, 2023), the water's pH was increase at rate of 0.23/per two-weeks interval with lower values during the wet season May to March (MAM) and slightly higher values during the dry season June to August (JJA).

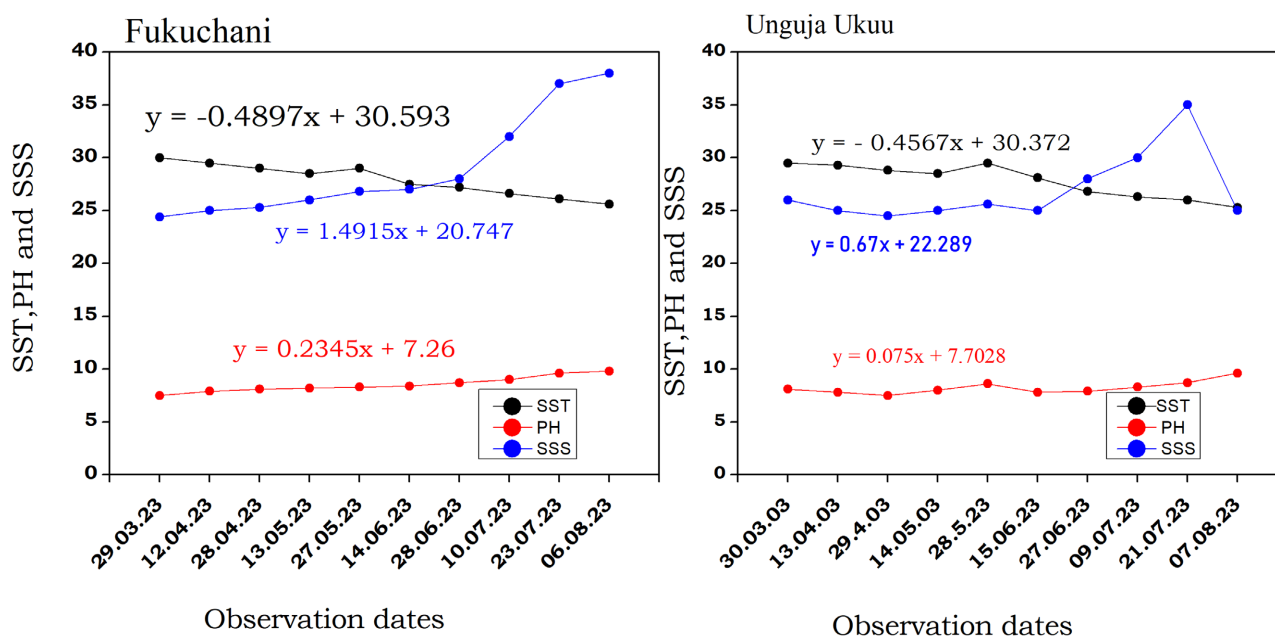


Figure 2. Variability of SST, pH and SSS at Fukuchani and Unguja Ukuu region.

The pattern shown in **Figure 2** could be explained due to the fact that during MAM the water temperature was slightly high and during the JJA the water temperature was decreasing, indicating a slight increase of pH, as agreed by [Günay et al. \(2015\)](#), who noted that the impact of SST on pH is indirectly caused by salinity. Though warming of waters decreases solubility of water, a decrease in SSS result-

ing in high pH dominates the impact of solubility. As for the variation of salinity at Fukuchani site, **Figure 2** (left panel) reveals very little variation in salinity and seems to be constantly low during wet days. This could be due to the fact that the increased freshwater flux (heavy rainfall) dilutes the saltiness of the water. Also, **Figure 2** shows that during dry and cold days (JJA), the salinity was increasing. These findings are in agreement with a number of studies including **Asha and Muthiah (2005)** who noted that both SST and salinity controls the water density which play a role in controlling the oceans currents with their inverse relational results in which also reveal that for the 16 weeks' period the salinity at Fukuchani was increasing at a rate of 1.49/two weeks. The variability of SST at Fukuchani (**Figure 2**) shows that SST was decreasing at a rate of -0.48°C /two weeks. Its trend was first seeming to be constant in wet days (MAM) and then sharply decreasing in dry and cold days (JJA). Like the pH, salinity and SST results, the presented results in **Figure 2** are well supported by **Kai et al. (2021)**, and **Ijmtst (2015)** who noted that about 80% of the freshwater flows on Earth's surface occur over the ocean, and as evaporation and precipitation patterns change, the surface salinity of the ocean responds by exhibiting anomalies that are either salty or fresh. Also, these results show that the SST was low during dry cool season, and the ocean water tends to be cold as well, as supported by **Donguy and Meyers (1999)**, who noted that salinity rises in the equatorward of 5°N during the southwest monsoon (JJA), probably as a result of upwelling and evaporation. The variability of SST, pH and sea surface salinity (SSS) for Unguja Ukuu presented in **Figure 2** reveals that there are slight differences to Fukuchani intern of SSS, SST, and pH in both seasons of MAM and JJA, where SSS was 0.96 ppt/2 weeks, SST was 0.45°C and pH was 0.075/2 weeks, and all parameters were affected nearly the same way in Fukuchani. As for Unguja Ukuu, these parameters had shown a minor influence on the growth of sea cucumbers. Also, the trend of SST was first seeming to be constant in wet days (MAM) and then sharply decreasing in dry and cold days (JJA), as at Fukuchani. While a five-month study may not capture the complete growth cycle, the study's timeframe encompassed distinct wet and dry seasons, enabling the detection of significant variations in sea cucumber growth.

3.2. The Influence of Carbonate on Sea Cucumber Growth

The influence of carbonate on the growth of sea cucumber was investigated using soil samples, and the results show that the level of carbonate at Fukuchani was higher compared with Unguja Ukuu on both sampling periods (**Figure 3**). More results in **Figure 3** show that through the entire investigation period, the carbonate at both sites was slightly changing, i.e., no significant changes in carbonate were observed for the two periods (first sampling and last sampling). Based on the soil carbonate, it has been noted that the best growth performance was found as significant in the 1 mm sediment group. Sediment is an absolutely necessary material for not only feeding sea cucumbers but also for burrowing and well-being of these benthic organisms. **Lee et al. (2018)** also tried to correlate the growth rate

of sea cucumber with the carbonates as indicated in this study. His finding showed that sediment characteristics significantly affect sea cucumber growth and survival.

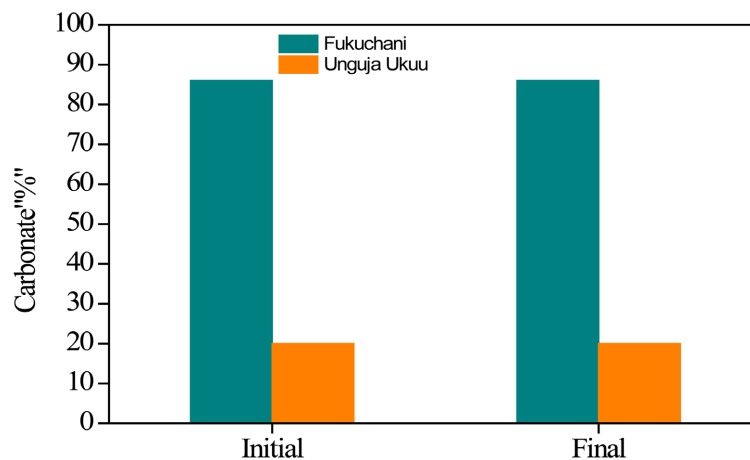


Figure 3. Percentage carbonate concentration measure from the soil samples of Fukuchani (blue) and Unguja Ukuu (Orange).

3.3. The Influence of Particle Size to the Growth of Sea Cucumber

Laboratory analysis of particle size at Fukuchani and Unguja Ukuu revealed dominant particle size ranges of 0.185 - 0.25 mm and 0.23 - 0.35 mm during initial and final sampling, respectively. These ranges align with findings by [Sabilu et al. \(2021\)](#), who reported optimal sea cucumber growth within a 0.25 - 1 mm particle size range. Fukuchani exhibited a finer particle size distribution compared to Unguja Ukuu. Furthermore, the sediment at both sites was predominantly composed of medium to fine sand, consistent with observations by [Sabilu et al. \(2021\)](#) and [Namukose et al. \(2016\)](#). [Namukose et al. \(2016\)](#) suggested a correlation between sea cucumber size and sediment particle preference, with larger individuals absorbing finer sand and smaller individuals absorbing medium-coarse sand. However, it is important to note that this study did not directly analyze grain size within the sea cucumber gut. Future research should investigate this aspect to provide direct evidence of particle size selection by these animals.

3.4. Influence of Chlorophyll

The results of the investigation of chlorophyll concentration at the two sites show that Fukuchani had a higher concentration than Unguja Ukuu. Further results revealed that the chlorophyll concentration was increasing with time, indicating higher concentration during the cold season than at the wet season ([Figure 4](#)).

The study infers a link between increased chlorophyll-c concentration and sea cucumber growth based on the established relationship between chlorophyll-c and algal biomass, a known food source for sea cucumbers. [Hartati et al. \(2019\)](#) and [Christou et al. \(2022\)](#) are cited to highlight the observation that chlorophyll-c concentrations increase during colder seasons (JJA). Chlorophyll-c is recognized

as an indicator of diatom and green algal biomass within sediments.

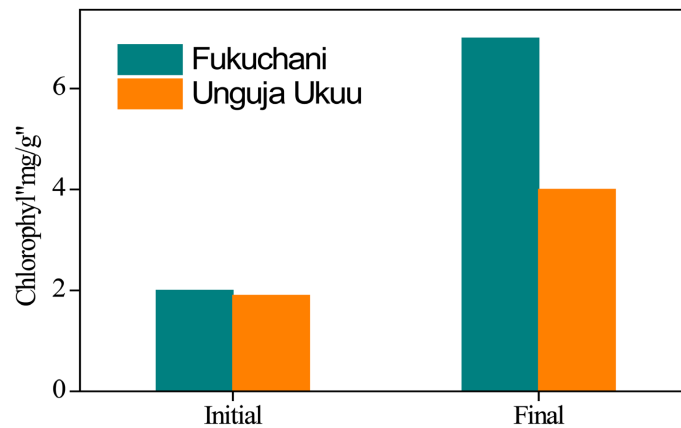


Figure 4. The chlorophyll concentration for the two study sites (a); the result of chlorophyll (mg/g).

3.5. Length and Weight Relationship of Sea Cucumbers at Fukuchani and Unguja Ukuu

The results of the growth characteristics based on the length and weight relationship revealed that the sea cucumbers at Fukuchani increased at an average rate of 1.34 g/day, while those at Unguja Ukuu increased at 1.28 g/day. As for length changes, sea cucumbers at Unguja Ukuu increased at a rate of 0.81 mm/day, while those at Fukuchani increased at 0.86 mm/day. These average daily growth rates (AGR) were calculated by dividing the total increase in weight or length by the number of days in the study period. To ensure accurate growth tracking, individual sea cucumbers were tagged and measured consistently throughout the study. The higher AGR and specific growth rate (SGR) observed at Fukuchani compared to Unguja Ukuu could be attributed to the contrasting environmental conditions between the open sea location of Fukuchani and the inland location of Unguja Ukuu.

The study found that sea cucumbers in Fukuchani grew faster at the rate of 1.34 g/day than those in Unguja Ukuu at the rate of 1.28 g/day both in terms of weight and length. This difference in growth rates may be attributed to the different environmental conditions, with Fukuchani, being located on the open sea, offering more favorable conditions for sea cucumber growth (**Figure 5**).

On the side of SGR, the length and weight relationship reveal that, as for Fukuchani, the SGR was 1.509 g/day, while that of Unguja Ukuu was 1.319 g/day. As for change of length, on the side, SGR result revealed that the sea cucumber at Fukuchani increased its length by rate of 0.603 cm/day and for Unguja Ukuu, was increased by a rate of 0.546 cm/day. The results of the Pearson correlation (r) presented in **Figure 6** for Unguja Ukuu revealed that SST has a strong significant negative correlation with sea cucumber growth. Similar case holds for Fukuchani where the correlation between the two parameters (i.e., SST and growth) was $r = -0.98, 0.98$ and 0.83 at ($p \leq 0.01$).

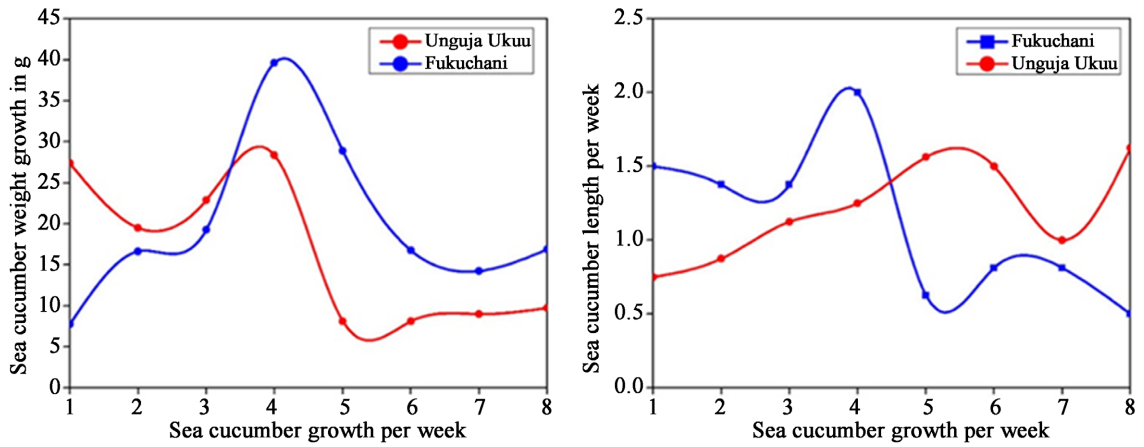


Figure 5. Comparison between average sea cucumbers' weight and length at Fukuchani and Unguja Ukuu.

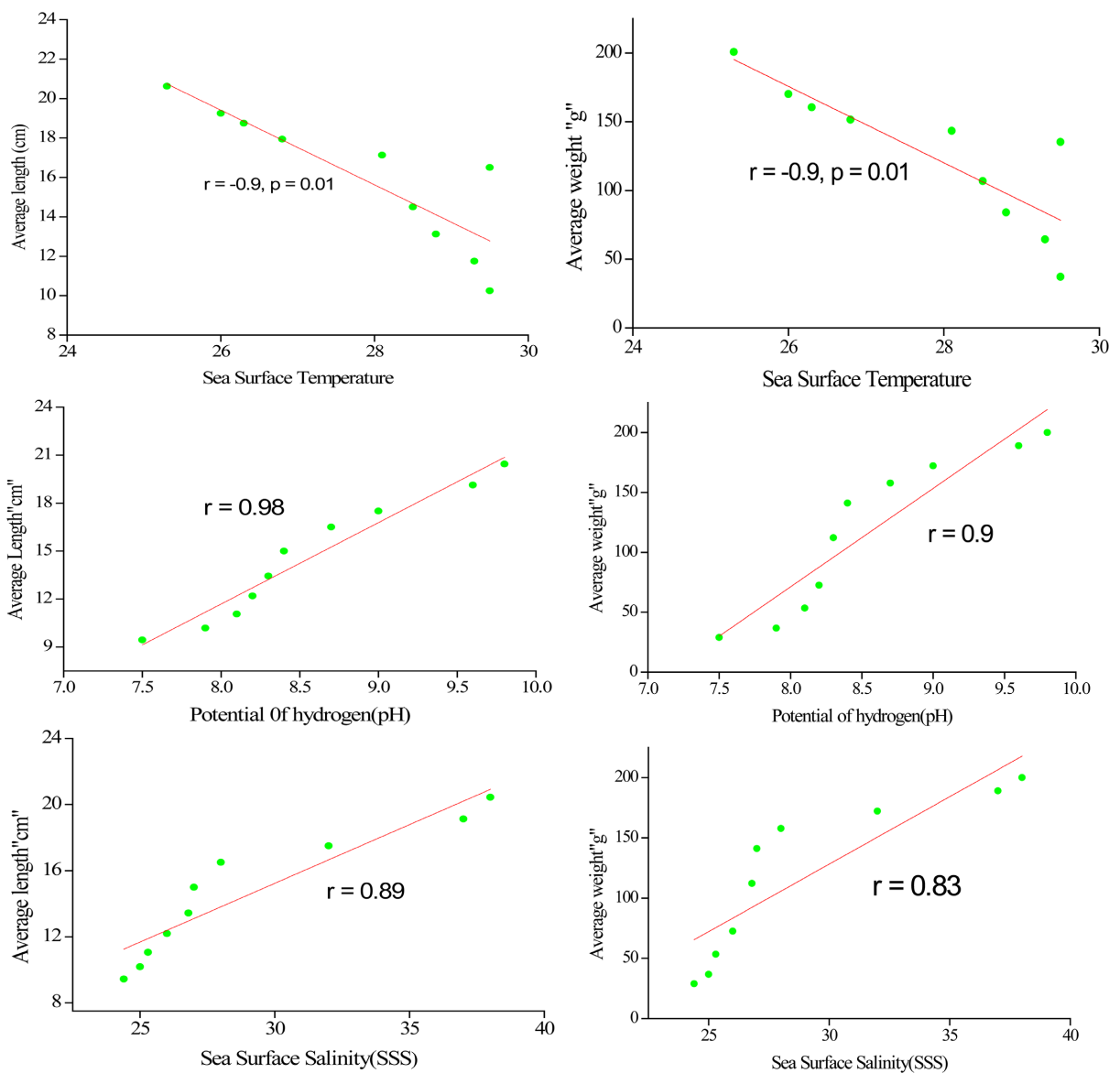


Figure 6. Correlation of average length and weight for SSS, SST and pH.

While the present study observed a correlation between increased SSTs and potential declines in sea cucumber growth over a five-month period, as supported by Günay et al. (2015) who highlighted temperature's significant role in sea cucumber physiology and metabolism, the reviewer rightly points out the limitations of extrapolating these results to long-term climate change effects. The cited study, Christou et al. (2022), which utilized satellite imagery to analyze spatial-temporal variability of oceanographic parameters and their relationship to *Holothuria* species abundance in a Mediterranean MPA, provides a broader context. While that study focused on a specific MPA, its methodology and findings underscore the sensitivity of sea cucumber populations to environmental fluctuations, including temperature. The study demonstrated the feasibility of using satellite data to monitor long-term environmental parameters and track species abundance. On the other side, climate change projections indicate a sustained increase in SSTs globally, with potential for more frequent and intense heatwaves (IPCC, 2021). These changes, even if seemingly gradual on a yearly scale, can accumulate and exert significant stress on marine organisms with narrow thermal tolerances, such as sea cucumbers. Climate change also influences other environmental factors, like ocean acidification and changes in nutrient availability, which can indirectly affect sea cucumber growth and survival (Dupont et al., 2010).

4. Conclusion

This study explored the factors influencing sea cucumber growth in Unguja Ukuu and Fukuchani. The results indicated that Fukuchani provided a more favorable environment for sea cucumber growth as compared to Unguja Ukuu. Chlorophyll concentration was found to positively impact sea cucumber growth, particularly during the cold season. Additionally, the study highlighted the influence of particle size and carbonate content on sea cucumber growth.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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