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Vegetation Characteristics and Deforestation at Two Mangrove Ecosystems Subjected to Varying Anthropogenic Influences: Case of Mtoni and Dege, Dar es Salaam, Tanzania

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ABSTRACT

Mangrove ecosystems are subject to over-exploitation, pollution, and conversion to other land uses from anthropogenic pressures. To understand the way different mangrove species, respond to the anthropogenic impacts, Mtoni and Dege mangrove ecosystems, with varying degradation levels were compared on vegetation characteristics, deforestation, and abiotic variables. The study adopted the line transect permanent plots method. In each sampling plot, mangrove vegetation characteristics and selected abiotic variables were assessed. Mangrove vegetation characteristics were tested using an independent t-test and a special t-test. Mangrove species diversity was calculated using Shannon-Wiener Index. Relationships of variables were tested using Spearman's rank correlation coefficients. Findings showed that Mtoni had higher mangrove species diversity, richness, and evenness than Dege. Dege showed significantly higher mangrove density, basal area, and regeneration than Mtoni. Stump density was significantly higher at Mtoni than at Dege. In Mtoni, the basal area was significantly negative correlated with both salinity and organic matter. In Dege, basal area and salinity were significantly positive correlated. There was high mangrove degradation at Mtoni compared to Dege. It is recommended that participatory conservation and management interventions be undertaken. Mere protection from further exploitation is sufficient for Dege, while active restoration is recommended for Mtoni.

Key words: Mangrove forests – species diversity – sapling regeneration – mangrove deforestation.

INTRODUCTION

Mangroves refer to a diverse group of salt-tolerant plants that inhabit the intertidal margins of low-energy coastlines, mudflats, and river banks in tropical and sub-tropical areas (Friess *et al.* 2019, UNEP 2014). Mangroves form a complex community below the high tide mark on sheltered tropical shores (Diniz *et al.* 2022, UNEP 2014). They often form a borderline between the oceans and tropical rain forests; they comprise trees and shrubs belonging to 12 genera in 8 different families worldwide. The dominant mangrove genera are *Rhizophora*, *Avicennia*, *Sonneratia* and *Bruguiera* (Malik *et al.* 2015). More than 50% of the world's 100,000 km^2 mangrove forests are found in the eastern hemisphere (UNEP 2014, Linneweber 2013).

As highlighted by Webber *et al.* (2016), mangrove ecosystems are important for millions of people around the world as they support both subsistence and commercial fisheries, and provide many other ecological and socio-economic benefits. These ecosystems also contain high biodiversity of animals and plants and provide opportunities for ecotourism and education-related activities (Thomas *et al.* 2018). However, large mangrove areas are subject to increasing pressures from a variety of anthropogenic activities such as agriculture, prawn farming, fishing, salt making, waste disposal, settlements, and cutting of mangroves for fuel, timber, and building poles (Branoff 2017). These pressures threaten mangrove ecosystems, and their affiliated ecosystems of coral reefs and sea grasses, the consequences of which include loss of valuable mangrove resources and a reduction in mangrove ecosystem production, unless effective management initiatives are undertaken (Feka and Morrison 2017).

In Tanzania, mangroves occur along the coast from the border with Kenya in the north to that of Mozambique in the south and around many of the islands off the coast (Basha 2018, Mangora 2016). Recent remote sensing data estimates the total coverage of mangroves in Tanzania at 133,500 ha (Basha 2018, Brown 2016) with major species being *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Heritiera littoralis*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *Sonneratia alba*, *Xylocarpus granatum* and *Xylocarpus mullucensis* (Mangora 2016, Mohamed 2004).

Mangrove ecosystems are threatened by the impacts of anthropogenic pressures (Diniz *et al*. 2022, Basha 2018, Branoff 2017, Feka and Morrison 2017). However, the response of various mangrove species to these pressures in respect of their resilience is scantly investigated. This study, therefore, investigated the phenological and species diversity-based responses of the two mangrove forests (Mtoni and Dege) varying in their anthropogenic influences along the coast of Dar es Salaam to establish the level of interventions required for protection or restoration. Specifically, the study aimed at assessing mangrove species diversity, density, and basal area, examining the extent of mangrove harvesting, and evaluating the relationship of mangrove basal area with the selected abiotic factors. In lieu of these, the study tested the following hypotheses:

i. Mangrove species diversity, density, and basal area are greater in Dege than in Mtoni
ii. The extent of mangrove harvesting is greater in Mtoni than in Dege
iii. Mangrove basal area is positively correlated with sediment organic matter.

MATERIAL AND METHODS

The study sites

This study was carried out in the Dege and Mtoni mangrove ecosystems, all located along the coast of Dar es Salaam in Tanzania (Figure 1). These sites were selected because they are large mangrove ecosystems subjected to large human populations that potentially threaten their existence. Dege mangrove ecosystem is found at the mouth of Bandarini River, which is a seasonal stream. It is located at latitude 6° 52' S and longitude 39° 28' E. Its distance from Dar es Salaam city center is about 60 km.

Dege mangrove ecosystem is estimated to cover 245.0 ha, with its main mangrove species being *Ceriops tagal*, *Rhizophora mucronata*, *Sonneratia alba*, *Avicennia marina*, *Xylocarpus granatum* and *Bruguiera gymnorrhiza* (Mtanga and Machiwa 2008). The inhabitants of Dege village depend largely upon marine and coastal resources. Their settlement is located just 3.3 km from the mangrove forest, posing great threats to the forest by harvesting mangroves for building poles, firewood, and boat construction (Kristensen *et al.* 2011).

Mtoni mangrove ecosystem is found along the two creeks, Kizinga and Mzinga, which flow into the Mtoni estuary near Mbagala. It is located between the latitude 6° 45' S, and longitude 39° 41' E, at a distance of about 20 km south of Dar es Salaam city center. This study was conducted along the Mzinga creek, which is approximately 1.5 km across.

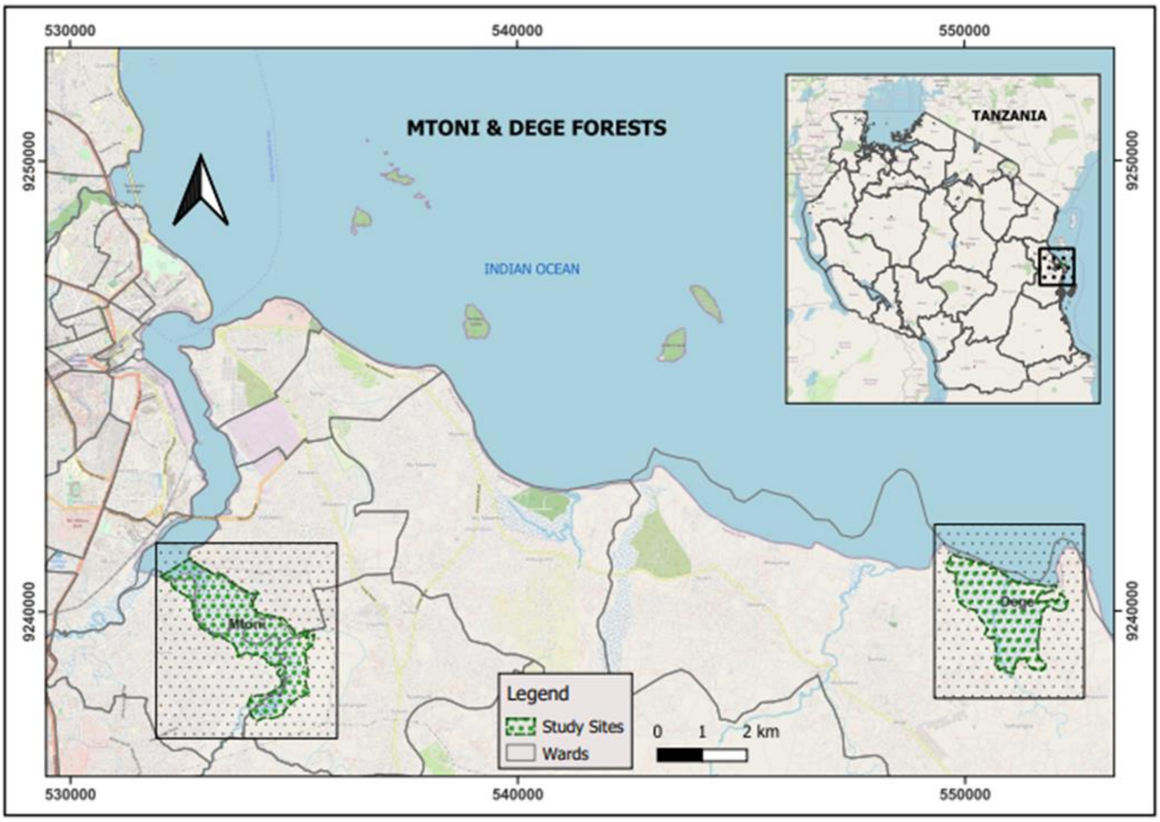

Figure 1. The coast of Dar es Salaam showing the location of the study sites. *Source*: University of Dodoma GIS Laboratory, 2022.

Mtoni mangrove forest is estimated to cover 378.4 ha, with dominant mangrove species being *Sonneratia alba*, *Rhizophora mucronata*, *Avicennia marina*, and *Ceriops tagal* (Mgaya *et al.* 2004). Mtoni mangrove ecosystem is impacted by anthropogenic activities through cutting down trees for fuel wood and building poles, and domestic and industrial pollution (Mihale *et al.* 2021).

Characteristics of human populations near the study sites

Dar es Salaam city is situated on Tanzania's east coast at latitudes 6°45' S and 7°25' S and longitudes 39°E and 39°55' E. It shares borders with the Coast Region to the north, west, and south, as well as the Indian Ocean to the east. Dar es Salaam city has a total land area of 1,630.7 km^2 (Moshi *et al.* 2018). The coastal plain and the inland plateau make up the two distinct geographies of Dar es Salaam city. Site elevations range from less than 5 meters above sea level (asl) in the lowlands along the coast to 60-150 meters above sea level (asl). The annual rainfall in the Dar es Salaam city is above 1,000 mm, with two distinct rainy seasons; March to May and October to December (Manara 2020). The city's average monthly relative humidity ranges from 72% in January to 82% in April, with a mean annual temperature range of 30.8^o C to 21.3^o C (Ndetto and Matzarakis 2013).

Dar es Salaam city is estimated to have a population of 7 million people, making up 8% of the national population (www.worlpopulationreview.com). Over 70% of the country's gross domestic product (GDP) is produced in Dar es Salaam city, and about 70% of its residents rely on fuelwood like firewood and charcoal for their energy needs (Lyimo 2006). Due to the profitability of the wood industry, illegal logging occurs. The future of Dar es Salaam's natural environment is in danger due to the mangroves being destroyed by deforestation and soil erosion. People living near the Dar es Salaam coast pose socioeconomic threats to mangroves by cutting down mangroves for fuel used in making salt, burning lime, and smoking fish (Maseta *et al.* 2021). Along the coast of Dar es Salaam city, human populations are also responsible for the removal of mangroves for settlements and poles, as well as by trampling (Mabula *et al.* 2016).

Research design and sampling procedures

The study adopted the line transect permanent plots sampling design (English *et al.* 1997). In each study site, transects were established perpendicular to vegetation zones, covering the whole area from the lower to the upper parts of the creek passing through the mangrove forests. Along each transect, 10m x 10m sampling plots with a distance of 20m between plots, were established. At Mtoni, 6 transects were set, while at Dege 7 transects were set. In each transect, 4-8 plots were established depending upon the length of transect. A total of 79 sampling plots (31 for Mtoni and 48 for Dege), as the sample size (n), was established. The Global Positioning System (GPS) readings were recorded for all plots.

Quantification of mangrove vegetation characteristics

In each sampling plot, all mangroves were identified to species level and counted according to their maturity categories. The girth at breast height (GBH, standardized as 1.3m above ground) of trees (>8cm in girth) and saplings (<8cm in girth, > 1m in height) were measured using a tape. Seedlings (<1m in height) were also identified to species level and counted. All stumps of cut trees were counted and the girth at the top was measured. If species of stumps could be identified, this was also recorded.

Measurement of the abiotic factors

Abiotic factors were measured in each study site in the same sampling plots that were selected for the quantification of mangrove species.

Sediment interstitial salinity: Interstitial water was drawn from the sediment using a 20-ml syringe. A few drops were then placed in a refractometer to measure salinity in parts per thousand (ppt).

Percent saturation capacity: One random sediment sample was collected in each sampling plot. Approximately 10g from each sample was completely saturated, weighed, placed in a porcelain crucible, and dried in an oven at 105 °C to a constant weight. The percentage loss in weight was then calculated to give percent saturation capacity.

Sediment organic matter content: The ignition method was used to determine the sediment organic matter content of each sample that had been dried for obtaining percent saturation capacity. Sediment samples were burnt at 500°C for 4 hours and then cooled in desiccators. Organic matter content was obtained by calculating the percent loss in weight.

Data analysis

Data from the two study sites were assumed to be independent, normally distributed, and have a homogeneity of variance. With a guide from the three study hypotheses, these data conditions enabled differences in the mangrove density and the basal area, as well as the level of mangrove harvesting between the two study sites, to be tested using the two-sample/independent t-test with a probability of 0.05, and the degrees of freedom (df) of 77 (i.e., $n_1+n_2 - 2$). Mangrove species diversity was calculated for each study site using the Shannon-Wiener Index of species diversity, which takes into consideration the number of species as well as the evenness of the abundance of each species (Nolan and Callahan 2006). It was calculated by taking the number of each species, the proportion of each species, and summing up the proportion times the natural logarithms of the proportion for each species as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where; H' = species diversity index, s = number of species, and pi = proportion of individuals of each species belonging to the *i*th species of the total number of individuals.

The difference in diversity indices between the two sites was tested using a special t-test (Zar 1999), with a degrees of freedom (df) of 529 as it considered the number of individual mangrove species in all plots of the two study sites. Correlations between mangrove basal area and mangrove density, and the selected abiotic factors (i.e., sediment organic matter content, percent saturation capacity, and salinity) were tested using Spearman's rank correlation coefficients. This model measured the strength and direction (negative or positive) of the association between the mangrove biotic factors and selected abiotic factors in each study site.

RESULTS

Mangrove vegetation characteristics

Mangrove species diversity

Based on the Shannon-Weaner Index, mangrove species diversity was significantly greater in Mtoni (0.61) than in Dege (0.50) (special t-test for comparing indices of diversity: $t = 2.540$, $df = 529$, $0.01 < p < 0.02$), with 7 species being observed in Mtoni and 6 in Dege (Table 1). *Avicennia marina*, *Ceriops tagal*, *Sonneratia alba*, *Rhizophora mucronata*, *Bruguiera gymnorrhiza*, and *Xylocarpus granatum* were observed in both forests, while *Lumnitzera racemosa* was observed in Mtoni only.

Table 1. Species richness, evenness, and species diversity (Shannon-Weaver index) of mangroves for Mtoni and Dege forests along the coast of Dar es Salaam

Study site	No. of species	Evenness	Species diversity
Mtoni	7	0.72	0.61
Dege	6	0.64	0.50

Mangrove basal area

Mangrove basal area was significantly higher in Dege (1006cm^2/100-m^2 plot) than Mtoni (555cm^2/100-m^2 plot) (two-sample t-test: $t = 4.476$, $df = 77$, $p = 2.60 \times 10^{-5}$; Figure 2) at probability of 0.05. In Dege, *Ceriops tagal* had the highest basal area, followed by *Rhizophora mucronata*; while in Mtoni, *Avicennia marina* had the highest basal area followed by *Ceriops tagal* (Figure 3).

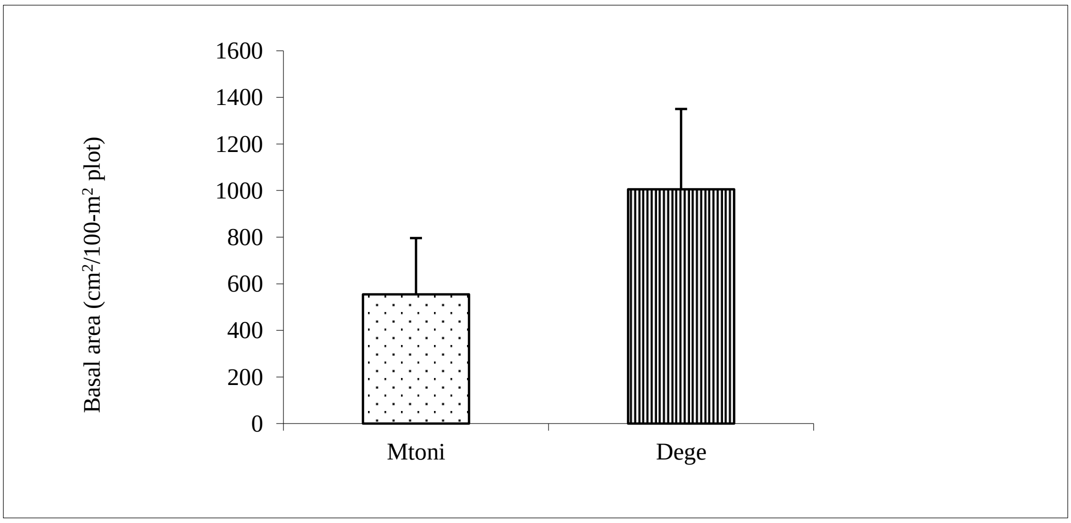

Figure 2. Stand basal area (mean + standard error) in Mtoni and Dege forests along the coast of Dar es Salaam.

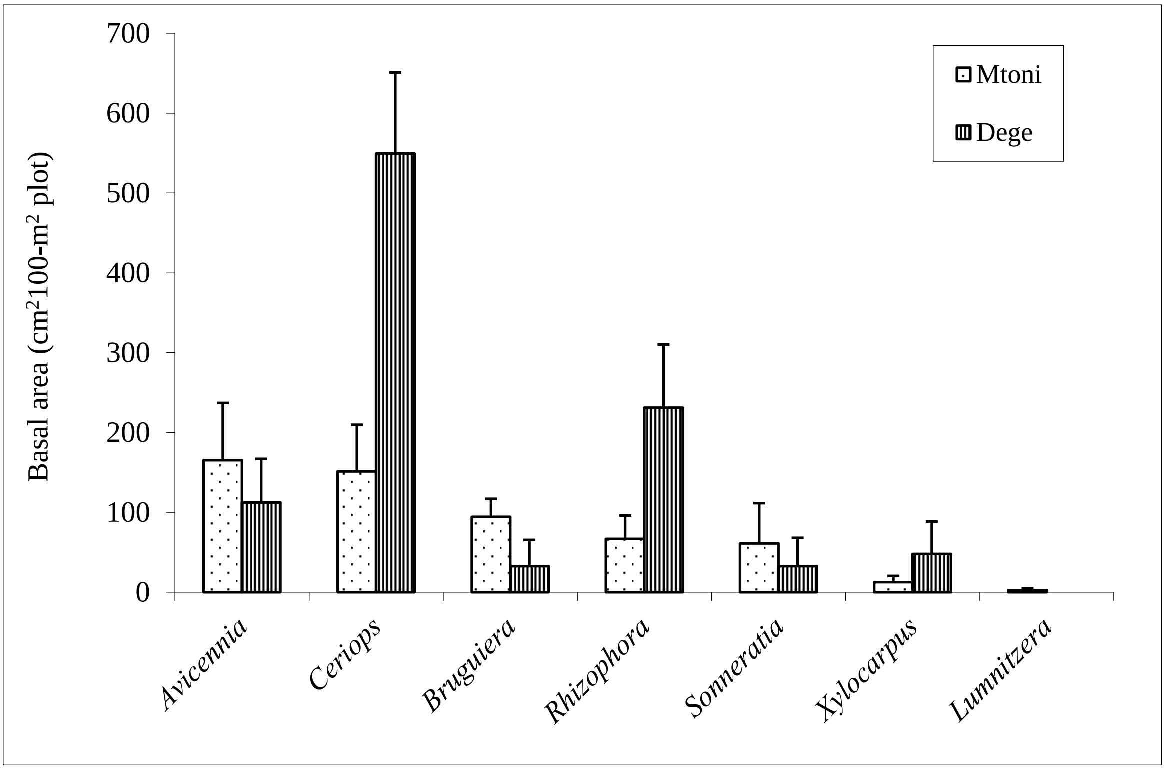

Figure 3. Basal area (mean + standard error) of various mangrove species in Mtoni and Dege forests along the coast of Dar es Salaam.

Mangrove stand density (taken as the total number of trees and saplings per unit area) was higher in Dege (251.6 trees/100-m^2 plot) than Mtoni (102.8 trees/100-m^2 plot) (two-sample t-test: $t = 2.821$, $df = 77$, $p = 0.00061$; Figure 4) at probability of 0.05. There was a higher density of all maturity categories at Dege than at Mtoni (Figure 5). In all study sites, *Ceriops tagal* was dominant in both tree and sapling categories, while *Avicennia marina* and *Ceriops tagal* seedlings were dominant in Mtoni (Figure 6) and Dege (Figure 7) respectively.

Mangrove regeneration

There was significantly greater regeneration (as indicated by the density of seedlings) at Dege (141.4 seedlings/100-m^2 plot) than Mtoni (36.1 seedlings/100-m^2 plot) (two-sample t-test: $t = 3.668$, $df = 77$, $p = 0.00045$; Figure 5) at probability of 0.05. At Mtoni, *Avicennia marina* had the most numerous seedlings (Figure 6), while at Dege; *Ceriops tagal* had by far the highest density of seedlings (Figure 7).

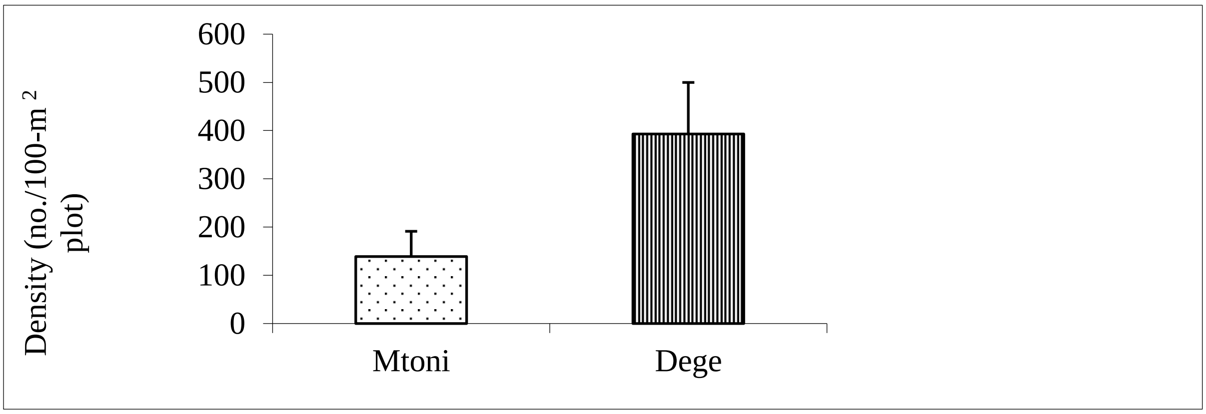

Figure 4. Mangroves stand density (mean + standard error) at Mtoni and Dege forests along the coast of Dar es Salaam.

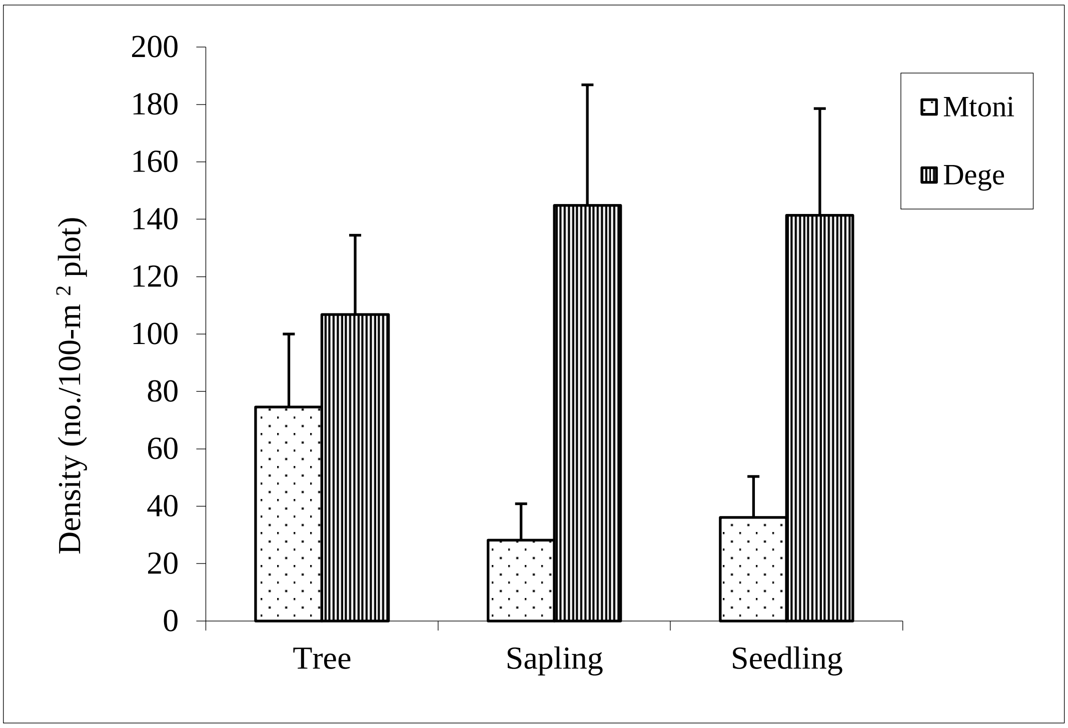

Figure 5: Total number of trees, saplings, and seedlings (all species combined; mean + standard error) at Mtoni and Dege along the coast of Dar es Salaam

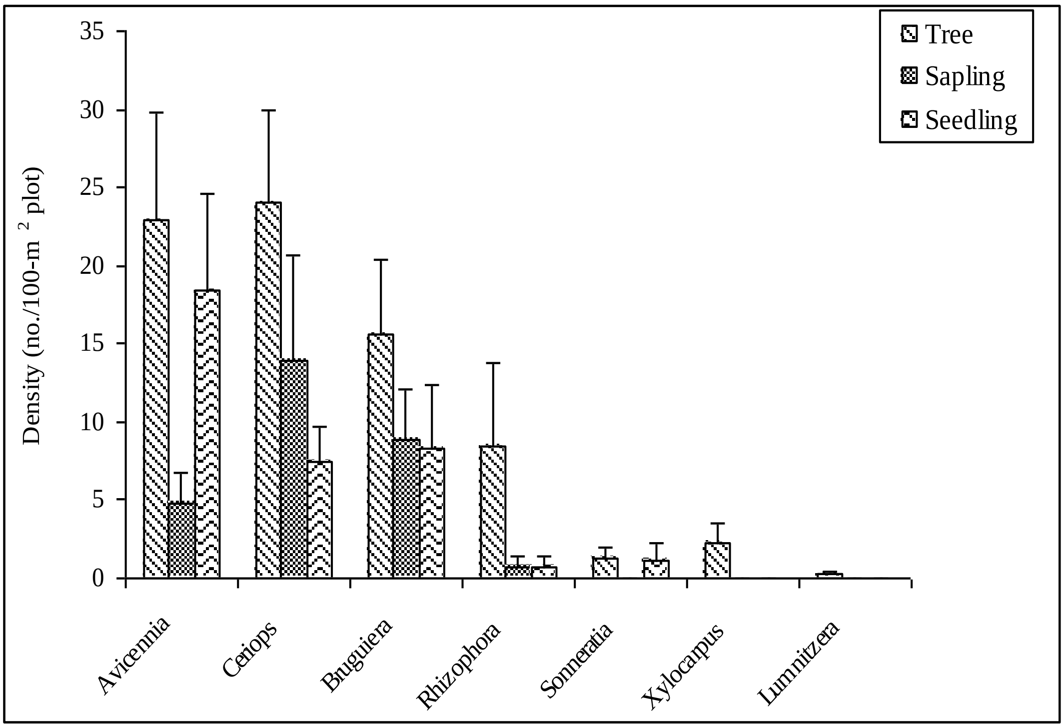

Figure 6. The density of mangrove species (mean + standard error) of various maturity categories at Mtoni forest along the coast of Dar es Salaam

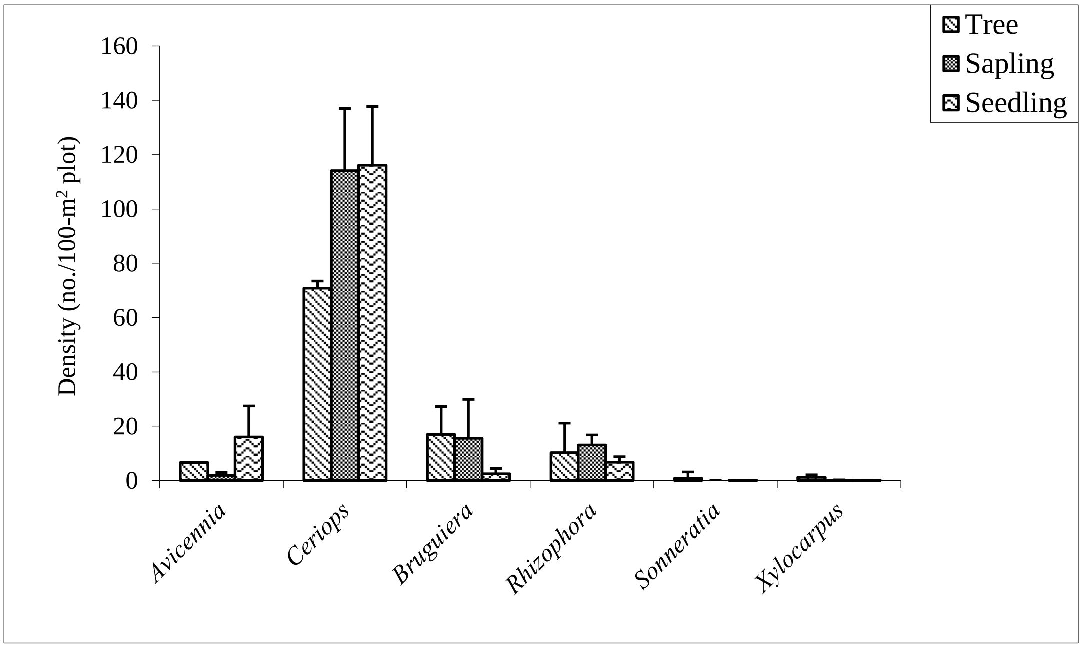

Figure 7. The density of mangrove species (mean + standard error) of various maturity categories at Dege forest along the coast of Dar es Salaam

Human pressures on mangroves

Mtoni had significantly higher mangrove stump density than Dege, with 38.7 stumps/100-m^2 and 25.9 stumps/100-m^2 plot respectively (two-sample t-test: $t = 2.182$, df = 77, $p = 0.0322$; Figure 8) at probability of 0.05. This indicates that mangrove degradation was high in Dege compared to Mtoni. In both sites, *Ceriops tagal* had the highest stump density, followed by *Rhizophora mucronata* at Dege and *Avicennia marina* at Mtoni (Figure 9). It implies that the preferences for these species (*Ceriops tagal* and *Rhizophora mucronata*) are high compared to other species. However, *Ceriops tagal* had higher stump density in Dege than Mtoni.

Selected abiotic factors

The findings for abiotic factors (organic matter, saturation capacity, and interstitial salinity) are shown in Table 2.

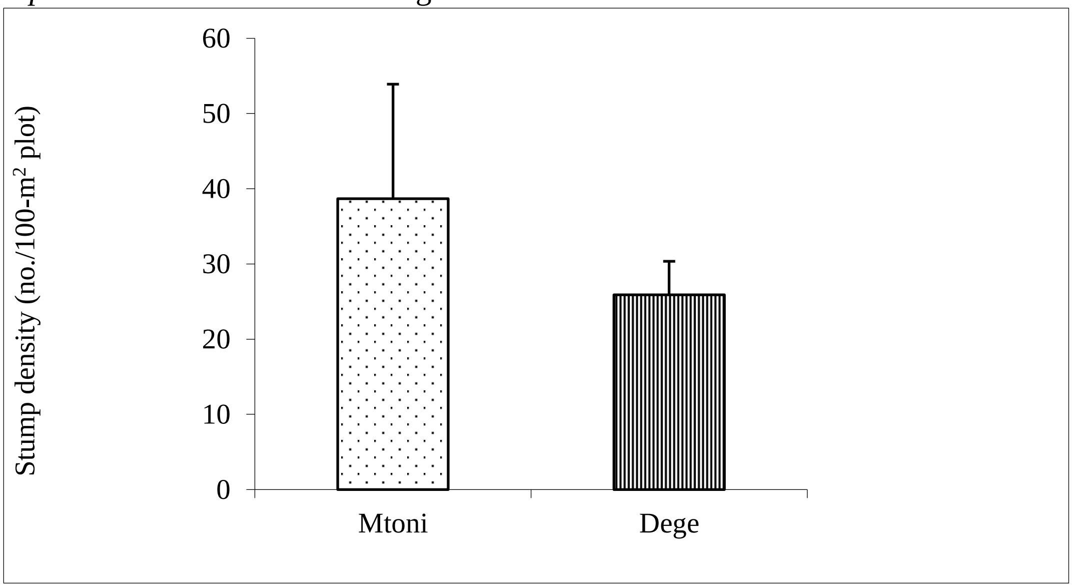

Figure 8. Stand stump density (mean + standard error) in Mtoni and Dege forests along the coast of Dar es Salaam

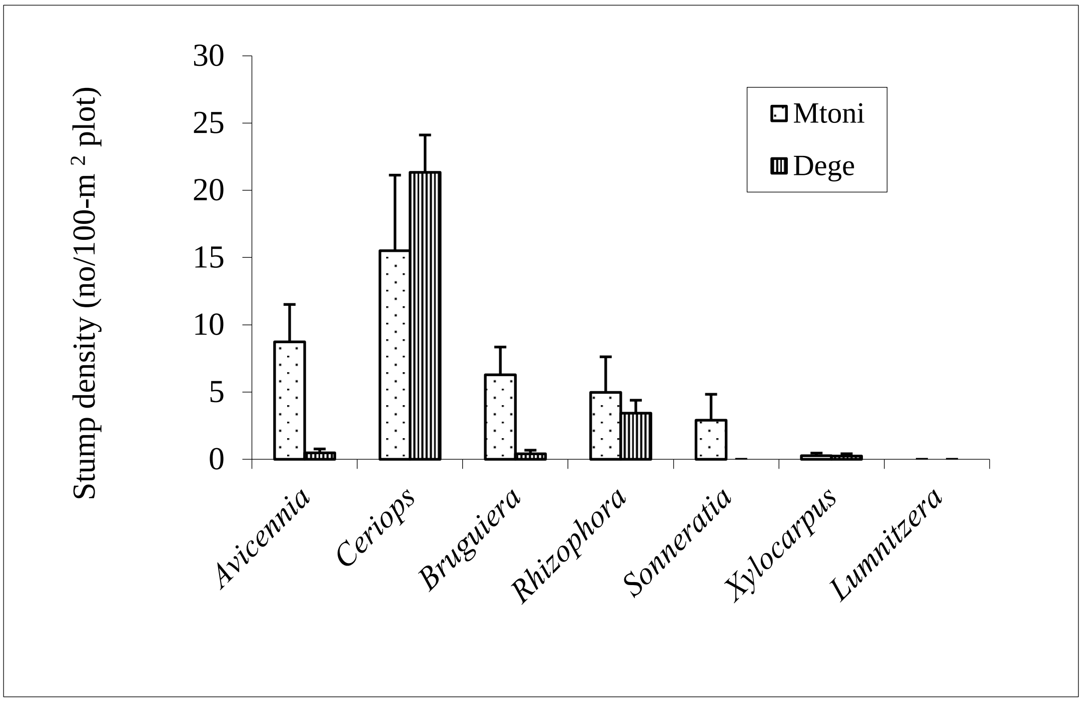

Figure 9. Stump density (mean + standard error) of various mangrove species at Mtoni and Dege forests along the coast of Dar es Salaam

Table 2. Abiotic factors as measured at Mtoni and Dege forests along the coast of Dar es Salaam

Abiotic factors	Mtoni			Dege		
	Mean	n	SE	Mean	n	SE
Organic matter (%)	6.5	31	1.6	5.1	48	0.4
Saturation capacity (%)	47.6	31	3.2	31.1	48	1.5
Interstitial salinity (‰)	34.2	31	0.2	32.4	48	0.4

Sediment organic matter

Percentage of sediment organic matter was significantly greater in Mtoni (6.5%) than in Dege (5.1%) (Two-sample t test: $t = 2.201$, $df = 77$, $p = 0.0307$) at probability of 0.05.

Percent saturation capacity

Percent saturation capacity was extremely significantly greater in Mtoni (47.6%) than in Dege (31.1%) (Two-sample t-test: $t = 5.265$, $df = 77$, $p = 1.23 \times 10^{-6}$) at probability of 0.05.

Sediment interstitial salinity

Sediment interstitial salinity was very significantly greater in Mtoni (34.2%) than Dege (32.4%) (Two-sample t-test: $t = 3.208$, $df = 77$, $p = 0.0019$) at probability of 0.05.

Correlations between mangrove vegetation characteristics and selected abiotic factors

At Mtoni, both basal area and mangrove density were significantly negatively correlated with percent organic matter (Table 3). While there was a significant negative correlation between basal area and salinity at Mtoni, the same parameters were very significantly positively correlated at Dege (Table 4). Organic matter and percent saturation capacity were very significantly positively correlated at both Mtoni and Dege. Mangrove density and mangrove basal area were also significantly positively correlated at Mtoni.

Table 3. Correlations between mangrove basal area and mangrove density, and selected abiotic factors at Mtoni forest along the coast of Dar es Salaam

	Mangrove basal area	Mangrove density	% Saturation capacity	% Organic matter	Salinity
Mangrove basal area	1.00				
Mangrove density	0.664 (<0.001) **	1.00			
% Saturation capacity	0.300 (0.101)	-0.246 (0.182)	1.00		
% Organic matter	-0.437 (0.014) *	-0.358 (0.048) *	0.877 (<0.001) **	1.00	
Salinity	-0.369 (0.041) *	-0.195 (0.292)	0.177 (0.339)	0.202 (0.276)	1.00

* = significantly correlated, ** = very significantly correlated. Values shown represent Spearman's rank correlation coefficients, with the probability of a Type I error in parentheses. n = 31

Table 4. Correlations between mangrove basal area and mangrove density, and selected abiotic factors at Dege forest along the coast of Dar es Salaam

	Mangrove basal area	Mangrove density	% Saturation capacity	% Organic matter	Salinity
Mangrove basal area	1.00				
Mangrove density	0.250 (0.90)	1.00			
% Saturation capacity	0.40 (0.792)	-0.330 (0.23)	1.00		
% Organic matter	-0.068 (0.651)	-0.221 (0.135)	0.856 (<0.001) **	1.00	
Salinity	0.464 (<0.001) **	-0.150 (0.313)	0.332 (0.322)	0.178 (0.230)	1.00

** = very significantly correlated. Values shown represent Spearman's rank correlation coefficients, with the probability of a Type I error in parentheses. n = 48.

DISCUSSION

Mangrove vegetation characteristics

The findings showed that mangrove species diversity and richness were greater in Mtoni than in Dege. This is contrary to what was expected according to Hypotheses No. 1. This may be due to the differences in the physical characteristics of the substrate. Dege has primarily rocky/muddy substrate, which is fairly uniform throughout the site. On the other hand, the substrate in Mtoni ranges from sandy in the upper zone to sandy/muddy in the middle zone and muddy in the lower zone. Due to the greater variation in the substrate, greater species diversity can be supported. In particular, the sandy substrate in the upper zone supports the additional species found, i.e., *Lumnitzera racemosa*.

Finding for this study found that there were 7 mangrove species in Mtoni, with a species diversity index of 0.61, which are both higher than previous studies by Akwilapo (2001) and Mgaya *et al.* (2004) who found 3 mangrove species with a species diversity index of 0.42; and 6 mangrove species with a species diversity index of 0.65 respectively. The greater number of species found in this study may be due to the greater area covered for mangrove assessment. Results for Dege also differ from what was reported by Sallema (2003) who found a total of 5 mangrove species.

The findings, that the mangrove basal area was higher in Dege than Mtoni, verify Hypothesis No 1. The main reason is the high rate of mangrove exploitation in Mtoni, where it was found to be 39 stumps/100-m^2 plot in comparison with Dege where it was 26 stumps/100-m^2 plot. Mangrove users tend to harvest the larger trees, leaving the smaller ones which contribute little to the basal area. Thus, in Dege, there is a greater abundance of larger trees remaining. An important factor leading to this difference is the fact that Mtoni is closer to Dar-Es-Salaam city center, and thus there is greater demand for mangrove products.

Comparing the results of this study with those of previous studies shows that there has been a drastic decrease in the basal area over time at Mtoni. Akwilapo (2001) found a stand basal area of 600 cm^2/25-m^2 plot and Mgaya *et al.* (2004) found a basal area of 446 cm^2/25-m^2 plot, while this study shows a basal area if converted to the same units, of 139 cm^2/25-m^2 plot. This suggests that mangrove cutting pressure has been increasing with time. The basal areas obtained in this study for Mtoni and Dege (252 cm^2/25-m^2 plot, if converted to the same units) are considerably lower than the values found in other mangrove forests in Tanzania that are located far from urban settlements, such as 1261 cm^2/25-m^2 plot reported for the Rufiji estuary (Wagner *et al.* 2003) and 1015 cm^2/25-m^2 plot reported for the Ruvuma estuary (Wagner *et al.* 2004). However, the basal areas for Mtoni and Dege are higher than those reported by Wagner (2005) for Mbweni and Kunduchi (85 and 64 cm^2/25-m^2 plots, respectively).

The fact that *Ceriops tagal* was dominant in both sites (with respect to both trees and saplings), may be due to preferential cutting of certain popular mangrove species, such as *Rhizophora mucronata* (used for building poles), as well as *Avicennia marina* and *Sonneratia alba* (used for firewood). *Ceriops tagal*, being short and bush-like in structure, is of little value to the people.

The dominance of *Ceriops tagal* corresponds with those of Masoud and Wild (2004) who noted that *Ceriops tagal* and *Rhizophora mucronate* were dominant species in Zanzibar, followed by *Bruguiera gymnorrhiza* and *Xylocarpus granatum*. The findings also relate to that of Mohamed (2004) who noted that the dominant species in Chake-Chake Bay are *Rhizophora mucronata* and *Ceriops tagal*. However, the findings of this study differ from those reported by Mgaya *et al.* (2004) that *Avicennia marina* had the highest density, followed by *Bruguiera gymnorrhiza* and *Ceriops tagal* in Mtoni. This is probably due to the fact that their study was conducted in only some areas where *Avicennia marina* was dominant; whereas, this study covered the whole area of Mtoni forest.

The higher regeneration capacity (as indicated by the density of seedlings) at Dege than Mtoni is probably related to the higher basal area and density of mangroves in the former site. Overexploitation of mature trees in Mtoni could have resulted in the absence of enough seedlings. It has been reported by Mabula (2017) that low regeneration can be caused by a lack of enough mature trees, absence of seedlings, seed predation, and strong tidal waves. Akwilapo (2001) and Wagner (2007) noted that the absence of *Sonneratia alba* seedlings in Mtoni was caused by fishermen who were dragging seine nets under the tree canopy.

The extremely high abundance of seedlings of *Ceriops tagal* in Dege is related to the fact that this species had by far the highest density of trees in that site. In Mtoni, there were high densities of *Avicennia marina*, *Ceriops tagal*, and *Bruguiera gymnorrhiza* seedlings. This could again, be due to the high tree densities of these species.

Human pressures on mangroves

The finding showed that mangrove stump density was higher in Mtoni than in Dege. This verifies Hypothesis No. 2. The reason could be due to the greater mangrove harvesting in Mtoni and subsequent degradation compared to Dege. It is likely due to the location of Mtoni which is near larger human populations, that puts higher exploitative pressure on the forest products, such as firewood, charcoal, and building poles. In both study sites, the *Ceriops tagal* had the highest stump density. This might be due to its high abundance and small size. Its small size in terms of diameter could facilitate its removal even by using a small hand tool. Thus, it has higher availability, even though it may not be the preferred species. Masoud and Wild (2004) reported *Ceriops tagal* to be the most exploited species in Zanzibar. Mfaume (2015) further notes that the stunted growth of *Ceriops tagal* is caused by both edaphic factors and anthropogenic overexploitation. Other species that followed for being exploited in both Mtoni and Dege are *Rhizophora* and *Bruguiera*. This was attributed to the fact that they are preferred for building poles and other construction works due to their good growth form and they usually attain intermediate size. However, Khamis *et al.* (2017) give general highlight that population increase, urbanisation, and emerging coastal activities confront mangrove forests in Tanzania.

Correlations between mangrove vegetation characteristics and selected abiotic factors

Even though more abundant mangrove growth increases organic matter, mangrove abundance (basal area and density) and organic matter content of the substrate were significantly negatively correlated in Mtoni, which is contrary to what was expected according to Hypothesis No. 3. This might have been due to the fact that, in some plots, there was a large number of small trees (especially *Ceriops tagal*), which contribute less to leaf litter resulting in little soil organic matter, while in other plots, there were few larger trees at a low density that contribute more leaf litter. Akwilapo (2003) reported Mtoni to have a high abundance of polychaetes due to the sewage input. Polychaetes act as shredders (Dean2008) and play a significant role in the decomposition of mangrove litter; therefore, reducing the residence time of organic matter (Alongi *et al.* 2005).

In Dege, there was a very significant positive correlation between basal area and salinity while the same parameters were significantly negatively correlated in Mtoni. It has been explained by Alongi (2008) that mangroves, especially *Avicenia marina*, have the ability to tolerate a wide range of environmental conditions such as salinity and air temperature, which allows them to thrive in both frequently inundated areas and infrequently flooded upper intertidal areas. A combination of other influences such as biotic factors may have been the cause for the significant negative correlation between basal area and salinity in Mtoni. This finding corresponds to the report by Ouyang and Guo (2020) and Satyanarayana *et al.* (2010) that there is a significant negative correlation between salinity and both mangrove density and basal area.

Organic matter and percent saturation capacity were very significant positive correlated in both Mtoni and Dege. Mamidala *et al.* (2022) and Yan *et al.* (2021) have also shown that there is a significant positive correlation between organic matter and percent saturation capacity. This can be explained by the fact that organic matter has the ability to conserve moisture for a longer period of time. Mangrove density and mangrove basal area were also significantly positive correlated in Mtoni. This situation might have been attributed to the presence of few seedlings and saplings which in turn contribute less to the basal area.

CONCLUSIONS

The findings from this study showed Mtoni to have higher mangrove species diversity than Dege. 7 mangrove species were observed in Mtoni and 6 in Dege. Dege had significantly higher mangrove basal area and density than Mtoni, undoubtedly due to lesser disturbance by human activities in the former. Regeneration capacity, as indicated by the density of seedlings, was greater in Dege than in Mtoni, which can be attributed to the higher abundance of mature trees in Dege compared to Mtoni. Mtoni had a significantly higher density of stumps than Dege. This indicates that there is greater degradation at Mtoni due to its close proximity to the Dar es Salaam city center, with its accompanying demands for firewood, charcoal, and building poles as well as the discharge of domestic and industrial pollutants. It is recommended that deliberate efforts to manage these mangrove ecosystems be devoted to mere conservation initiatives being undertaken for the Dege and active restoration for the Mtoni. Participation of the adjacent communities is crucial in ensuring sustainable management of these mangrove ecosystems. Awareness creation to the community, planners, and policymakers should also be extended for the safety of mangrove ecosystems.

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