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NATURAL REGENERATION OF MANGROVES IN A DEGRADED AND NON-DEGRADED TROPICAL FOREST OF ZANZIBAR ISLAND

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Abstract

The structure and natural regeneration patterns of mangrove forests were studied in the Zanzibar Island, Tanzania. A total of sixteen plots with an area of 100 m^2 were sampled and evaluated for trees and 25 m^2 for juveniles. Results of vegetation characteristics showed that the composition of mangroves differed significantly between the sites and species. Based on the species importance values, the dominant mangrove trees in Jozani was *Ceriops tagal*, followed by *Avicenia marina* in Kisakasaka and *Bruguiera gymnorrhiza* in Muwanda mangrove forests. Species density was in the order of *C. tagal* > *A. Marina* > *Rhizophora mucronata* > *B. gymnorrhiza* > *Pemphis acidula* > *Sonneratia alba*). In terms of individual area, Makoba and kisakasaka mangroves had significantly higher regeneration density than Uzi, jozani and Michamvi. The present findings revealed a clear relationship in the status of exploitation or degradation and the natural regeneration. In addition regeneration capacity was also proportion to species density. The impact of management regimes was depicted by significant lower number of regenerated trees along the Jozani Chwaka Bay National Park. This study provides valuable information for rehabilitation of mangroves and ecological sound management of mangrove biodiversity in the Zanzibar tropical Island.

Key words: Degradation; Natural regeneration, Regeneration class, Species.

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INTRODUCTION

Mangroves in Zanzibar are well developed in estuaries and confined to the protected bays and along the coast line of the entire island. The mangroves ecosystem is the second largest forest in Zanzibar after the coral rag forest, covered a total area of 18,000 hectares, where 6000 ha found in the main Island of Unguja and 12,000ha in Pemba Island [1]. Like in other mangrove forests in the world reduction of area of mangroves as a result of forest degradation has been taking place in Zanzibar coastal area [1, 3, 4, 5].

Most of coastal populations have grown over recent decades resulted in an increasing pressure on mangrove resources. For decades coastal communities have depended on mangrove as one of their sources of income [6]. This dependence has rendered the mangrove forests to severe exploitation. In Zanzibar the major factors for disappearance of mangrove forests includes over extraction of fuel wood and charcoal, construction materials for settlement, encroachment agricultural land and conversion to salt production and urbanization and industrialization [1, 7, 8,].

Many researchers have been reported unveiling the importance of the ecological, economic and protective role that mangroves fulfill. Increasing awareness of the true value of mangrove ecosystems has led to renewed efforts to protect and restore remaining mangrove stand in Zanzibar. As an example, Departments of Forest in collaboration with local groups started rehabilitation in different mangrove creeks since mid 90's. It was estimated that about 525 ha of mangroves was planted in 2007/2008 especially in most degraded areas [9], however no regular monitoring and evaluation to indicate how much those efforts are successful.

Mangrove forests are usually restored through natural regeneration, or via artificial restoration using planted seedlings. Through natural re-colonisation most of the local species occupy the shoreline and natural succession can take place [10]. The major advantage of natural regeneration is that the resulting forest is expected to be more similar to the local mangrove species. In addition, natural regeneration is relatively easy and more vigorously establish, less labour is required and result

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in minimum soil disturbance However, it may hampered by lack of seeds and propagules, weed competition, pollution, poor soil conditions or disturbed hydrodynamics of the site [11]. In this study, we assess the status of natural regeneration of mangroves after a long period of degradation and recent efforts of conservation of the coastal forests in Zanzibar Island. We determine 1) the mangrove vegetation characteristics and 2) regeneration capacity of existing mangrove species in Zanzibar

MATERIALS AND METHODS

Study site

Zanzibar is a tropical island located in the Indian ocean between latitude 04° 50" and 06° 30" South, and longitude 39°10" and 39° 50" East. The local climate is characterized by four distinct seasons; hot season "kaskazi" between December and February with little or no rain, the long rain "masika" occur from March to May. The relatively cool dry season "kipupwe" occurs between June and September, while vuli is short rainy season from October to November. The average rainfall varies from 1000mm to 2500mm per years while temperature ranges between 17^oC and 40^oC. The island is surrounded by the coral reefs, sandy beaches, lagoons, mangrove swamps which are rich in marine life.

This study was carried out in five mangrove sites with different degree of degradation and management status. Site 1 is Jozani Chwaka Bay National Park located about 35 km south-east of Zanzibar township in the South Region. It is the first and only National Park in Zanzibar lies in a shallow trough in the fossil coral bed between the mangrove filled bays of Chwaka and Uzi Island. The Jozani-Chwaka Bay Conservation Area has been upgraded to National Park in 2004 with an area over 2512 ha that includes the whole ground water forest, coral rag forest, mangroves and salt marshes. The area is an extremely rich mosaic of Zanzibar's diverse natural habitats, a sanctuary for biological diversity including rare, endemic and endangered species. Mangrove forests covering much of the eastern border as Jozani come into contact with Chwaka bay. Major mangrove species include *R. mucronata*, *C. tagal* and *A. marina*.

Site 2 is Uzi Island located in the southern part of Zanzibar in the Indian Ocean between 619' and 624` S and 39 25` E. This is Small Island with an area of about 15.6 km^2 and a population of 3200 peoples. The mangrove forest is found both in sandy and rocky shore in the northern tip and the southern part of the island. Eight species are reported to grow in this site include *R. mucronata*, *B. gymnorrhiza, C. tagal, A. marina, X. granatum*, *L. racemosa*, *S. alba* and *P. acidula* [12]. The mangrove forest is lie within Menai Bay Conservation area and nearby Jozani Chwaka Bay National Park. The Uzi mangrove stand serves as a feeding ground and a nursery ground for some commercial important species of fish [13]. These mangroves interact also with the terrestrial habitats, as Red Colobus and possibly other small mammals from the nearby Jozani Forest visit the Uzi mangroves in search for food [14].

Site 3 is Kisakasaka located about 15 kilometres from Zanzibar town with a population of 526 relying on mangrove forest. The mangroves forest cover an area of about 460 ha [1] where common mangrove species grow include *R. mucronata* , *C.tagal* and *A. marina*. In early 90's kisakasaka mangrove have been disappearing at tremendous rate, as a results a community-based management pilot project of forest resources was established in this area. Currently Kisakasaka Mangroves forest is under the Menai Bay Conservation area. This site is suitable to compare natural regeneration rate after long period of degradation and recent conservation effort from both community and government intervention.

Site 4 is Makoba Bay located in the northwest coast of Unguja Island. It is sheltered by the much smaller Tumbatu Island, which is located about 5 km offshore to the north. The bay has a total surface area of about 15 km^2 and average depth of 5 m with a volume of about $75x10^6$ m^3. Muanda mangrove forest cover an area of 520 ha which is found within the Makoba Bay [15]. In 2003 salt production was established around Muwanda, it was estimated that about 3 ha of mangrove area was cleared for saltpan [5]. Currently, Muwanda mangrove forest is under local management regime with a number of alternative activities in particular aquaculture.

Site 5 is Michamvi, a relatively remote peninsular which forms the upper part of the southeast coast of Zanzibar. To the east the land continues to be lined by the same broad coral lagoon of the adjacent Bwejuu area to the south. Five species of mangroves were common observed in this area, *A. marina*, *R. mucronata*, *B. gymnorrhiza, C. tagal* and *S. alba* (personal observation). Michamvi mangrove forest is not under any management program at the moment, since the site is useful to elucidate the impact of human pressure on regeneration of mangroves.

Data collection

A stratified sampling technique was used to sample mangroves in each site. Belt transects of 10m width were established both perpendicular and parallel to the forests in such away that they represented as good as possible the general mangrove forests of those sites. Vegetation sampling was carried out within 100m^2 quadrants, that were regularly laid along the transects. A total of 16 plots were studied in those mangrove forests. Within each quadrants individual tree greater than 300cm were identified and counted. Vegetation measurements included tree height and stem diameter were recorded from which were derived tree basal area, species density and frequency. Tree heights were measured in meters using tape measures stem diameter was measured in centimeter using tape measure.

Information on the composition and distribution pattern of natural regeneration was obtained using the method of Linear Regeneration Sampling. In 5x5 m^2 subplots(within the main 10x10 m^2 quadrants), occurrence of juveniles of different species was recorded and grouped according to their height classes. Seedling less than 40cm in height were classified as regeneration class I (RCI). Saplings between 40 and 150 cm height were classified as RCII, while RCIII was for all small trees with heights greater than 150cm but less than 300m

Data analysis

The ecological importance of each species was calculated by summing its relative density, relative frequency and relative dominance. The complexity indexes of the forests were obtained as the product of a number of species, basal area, maximum tree height (m).

Density was measured species wise and total in each plot as follows:

Density of each species (no/ha) = no. x 10,000 m^2 / area of plot in m^2

Total density of all species = sum of all species densities

Basal area was measured species wise and total in each plot as follows:

Basal area (m^2) of each species = 0.005 x DBH

Total basal area of all species (m^2/ha) = sum of all species basal area / area of plot in m^2 x 10,000 m^2

Relative density = no. of individuals of a species / total no. of individuals of all species x100

Relative dominance = total basal area of a species / basal area of all species x 100.

Relative frequency = frequency of species/ total frequency of all species in different plots x 100

Importance value of a species = relative density + relative dominance + relative frequency

Complex Index = number of species x stand density x basal area x height/100000

A two-tailed paired Student's t-test and one-way analysis of variance (ANOVA) were used to compare difference in species abundance between regeneration classes and stations. Post-hoc Tukey (HSD) and Fisher’s (LSD) tests were used to detect differences between treatments when significant differences were found. Results were considered significant if $p < 0.05$.

RESULTS

Mangrove Vegetation Characteristics

The composition of mangrove species, relative dominance, density, frequency and importance values of these species are presented in Table 1. Results of vegetation characteristics showed that the composition of mangroves differed significantly between the study sites and species. At site 1 Jozani mangrove forest, *C. tagal* had the highest density (53.13%) and the importance value of 123.7%. Meanwhile, *B. gymnorrhiza* had the significance lowest density both at site 1(Jozani) and site 4 (Muwanda) with recorded values of 10.49% and 14.4%, and less important value of 51.87% and 68.03% respectively. In contrary, *B. gymnorrhiza* had the highest density and important vales (42.94%, and 42.94%) at site 5 of Michamvi mangrove forest. On the other hand, *R. mucronata* turned to have the highest density of 46.84 and 34.62% at Nyeke and Muwanda mangroves (site 2 and 4 respectively), with importance value 106.84 and 82.79%. *S. alba* had the lowest rank at Nyeke and Michamvi (site 2 and 5) with density of 3.04 and 4.48%, and importance value of 16.91and 24.79%. Kisakasaka mangrove (site 3) showed different pattern of dominance to other sites, where *A. marina* had the highest density (47.07%) and importance value (104.09%), while the lowest rank was

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recorded for *P. acidula* (Table 1). In generally, of the six mangrove species subjected to analysis, *C. tagal* had the highest density when compared to other species regardless of sites. In term of species, the density was in the order of *C. tagal* > *A. Marina* > *R.mucronata* > *B. gymnorrhiza* > *P. acidula* > *S. Alba*.

Forest regeneration

The regeneration characteristic of juvenile mangrove species is described in terms of RCI (< 40cm in height), RCII (40 – 150cm) and RCIII (>150cm but < 300m) which differ significantly in densities and size class in all five sampling areas. The number of occurrence of RCI was significantly higher in Muwanda (8429±1608 trees per hector) than other study sites (*t*-test t=1.843, df=4 p=0.03). In contrast, RCII and RCIII were significantly higher at Kisakasaka (8809±1636 and 7315±1335 trees per hector respectively) when compared to Muwanda in terms of size and densities (*t*-test t=1.826, df=4, p=0.05). The lowest density was measured to Jozani mangroves which accounted for RCI (566±148 trees per hector), RCII (130±17 trees per hector) and RCIII (86±19 trees per hector). On the other hand, all regeneration class were higher at Michamvi compared to those of Jozani and Uzi mangrove forest (*t*-test, t=2.482, df=4, p=0.02; t=1.34, df=4, p=0.03; Figure 1). In terms of individual area, Muwanda and Kisakasaka mangroves had significantly higher regeneration density (*t*-test, t=2.988, df=4, p=0.005,) than Uzi, Jozani and Michamvi. However no significant different were found between these two forests (Figure 2).

Comparison of regeneration mangrove species at Kisakasaka show that *A. marina* was the most abundance species (9333±1826 trees per hector) followed by *B.gymnorrhiza* and *R. mucronata* (3888±377and 3187±551 trees per hector respectively), (ANOVA, F=3.236, df=4, 10; p<0.05). The least abundant species was *P. acidula* (100±47 trees per hector) which significantly differ to *A. Marina* (ANOVA, LSD multiple comparisons, p=0.001, Figure 3). In contrast, *C. tagal* was most abundant species at Muwanda (6367±1595 trees per hector), followed by *B.gymnorrhiza* and *S.alba* 4809±539 and 4250±1124 trees per hector). However there was no significant difference between regeneration species in this site (Figure 4).

The Uzi mangrove forest varies significantly in terms of size and densities of regeneration species (ANOVA, F=3.658; df=4, 10; p=0.04). *R. mucronata* was the most abundance regeneration species at Uzi island (665±92 trees per hector) followed by *C. tagal* (628±145 trees per hector) and *B.gymnorrhiza* (168±33 trees per hector). *R. mucronata* had significant higher number of regeneratin trees than *A. marina* and *P. acidula* (ANOVA, LSD multiple comparison, p=0.02). The lowest regenaration rate were recorded for *P.acidula* (12±5.6 trees per hector; (ANOVA, LSD multiple comparison, p=0.02; Figure 5). In Jozani mangrove forest, *C. tagal* was the most abundance regeneration species (483±146 trees per hector) followed by *R. mucronata* (267±74.9 trees per hector) and *B. gymnorrhiza* (32±6.7 trees per hector), but there was no significant different between species (Figure 6).

Our findings of regeneration mangrove species differ significantly at Michamvi (ANOVA, F=3.890, df=4, 10; p<0.03), where *B.gymnorrhiza* had the highest regeneration abundance than *A. marina*, *R. mucronata* and *S. alba* (ANOVA, LSD multiple comparison, p=0.02, p=0.001, p=0.02 respectvely). However, no difference was found between *B.gymnorrhiza* and *C.tagal* (1308±233 and 974±145 trees per hector respectively). Similarly there was no significant difference between *R. mucronata* and *A.marina*, while *S.alba* recorded the least regenaration status in the the area (Figure 7).

DISCUSSION

The occurrence of higher number of regeneration trees in Kisakasaka and Muwanda compared to those of Jozani depicting that these mangrove forest are under great human pressure such as cutting down of mangrove trees for energy fuels, construction materials for settlement, encroachment and agricultural land [2, 4]. Consequently, the presence of wide gaps in the affected areas allows full penetration of solar radiation which is among the necessary factors for the growth of plants [16]. Canopy gap creations are justified to be the key driver in the natural regeneration of the tropical mangrove, and in particular Rhizophora-dominated mangroves [17]. The use of mangrove timber has been reported in many area of Zanzibar Island and in particular Kisakasaka [1]. Salt production has been practiced in the past caused significant damage to some mangrove area include Makoba bay [5] This could also explain our results of the similar complex indices measured in Makoba and Kisakasaka mangrove forests.

The sites of Kisakasaka, Muwanda and Michamvi are an open access forest that likely to be impacted by human pressure than partial protected Uzi forest which is under Menay Bay conservation area and full protected forest of Jozani Chwaka Bay National Park. Despite of great opportunity and growing efforts of conservation in the Menai Bay area, it has not been enough and mangrove biodiversity losses continue at Uzi Island [12, 18]. Therefore the lower number of juvenile trees in a full protected area of Jozani is expected due to the impacts of management regimes.

Based on mangrove species, the mangrove density and higher importance values varies between species and sites. The present observations are consistent with other studies of mangroves diversity and distribution in Zanzibar Island, for example Hamad [19], who reported that *R. mucronata*, *B. gymnorrhiza*, *C. tagal* and *X. Granatum* are dominant species in Ngezi and Micheweni mangrove forest. According to Mchenga & Juma [12] *R. mucronata* and *C. tagal* were most abundant species at Uzi Island, Zanzibar. It was also reported that *A. marina* has the broadest distribution both latitudinal and longitudinal along tropical and subtropical coast of the East Africa [20].

This study revealed that regeneration capacity was proportion to species density. Therefore, natural re-colonisation of the local species occurs in these areas [10]. The composition of the regenerated species depends on the natural species of the nearby population. Naturally mangroves could disperse through self-planting or stranding strategies which will depend on the forest conditions (degraded or non-degraded), tides, as well as the stability of the soils [21].

At species level, *A. marina*, *C. Tagal* and *B. gymnorrhiza* recorded high regeneration density at different study sites. This observation is also supported by the previous works in Zanzibar Island (9, 19, 22]. In general, the difference in regeneration between one species and another depends on different factors such as type of soil and seed structure. For instance, *R. mucronata* is always dominant on muddy soil due to its prop roots that enable them to thrive well in an anoxic environment [22, 23, 24].

In conclusion, natural regeneration depends on the condition of the mangroves forest (degraded or non-degraded forest). The present findings revealed a clear relationship in the status of exploitation or degradation and the natural regeneration where the full protected forest of Jozani-Chwaka Bay National Park had the lowest regeneration density compared to the open access forest of Kisakasaka and Makoba. Regeneration capacity was also proportion to species density; therefore, natural re-colonisation of the local species occurs in these study sites. Further study should consider other important factors such as substrate, salinity, tidal currents, and availability of propagules, competition and other factors within the local conditions.

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Table 1. The table shows the species composition, relative dominance, density, frequency and importance values of mangrove

Relative values (%)						
Forest block	Species	Dominance	Density	Frequency	Importance value	Complex index
Jozani	*R. mucronata*	49.15	36.36	38.88	124.39	0.146
	C. tagal	26.13	53.13	44.44	123.7	
	B. gymnorrhiza	24.72	10.49	16.66	51.87	
Uzi	*R. mucronata*	28.57	46.84	31.43	106.84	0.39
	P. acidula	1.66	0.76	2.86	5.22	
	C. tagal	16.3	37.47	31.43	85.2	
	S. alba	8.16	3.04	5.71	16.91	
	A. marina	37.79	7.08	17.14	62.19	
	B. gymnorrhiza	10.2	4.81	11.43	26.44	
Kisakasaka	*A. marina*	31.64	47.07	26.09	104.8	0.08
	R. mucronata	25.9	30.95	34.78	91.63	
	C. tagal	10.97	4.42	15.22	30.61	
	B. gymnorrhiza	16.97	13.69	19.57	50.23	
	P. acidula	14.47	3.87	4.35	22.69	
Muwanda	*R. mucronata*	17.87	34.62	30.3	82.79	0.09
	B. gymnorrhiza	20.3	14.42	33.33	68.03	
	C .tagal	21.22	22.12	30.3	73.64	
	S. alba	40.1	28.85	6.06	75.01	
Michamvi	*A. marina*	33.26	15.38	23.21	71.85	0.159
	B. gymnorrhiza	29.07	42.94	28.57	42.94	
	C. tagal	10.46	17.30	23.21	50.97	
	R. mucronata	15.80	19.87	16.07	51.74	
	S. alba	11.39	4.48	8.928	24.79	

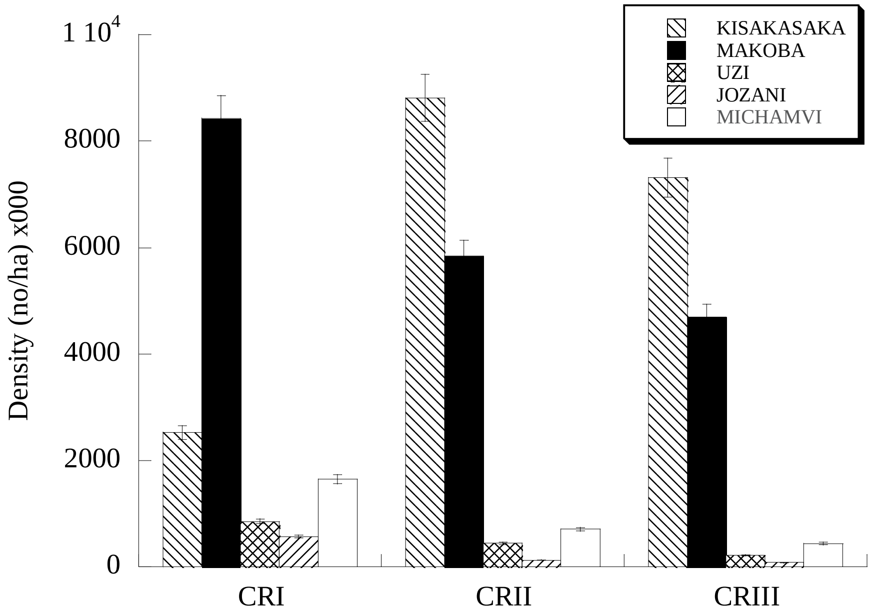

Figure 1. Comparison of regeneration characteristic of juvenile classes between mangrove sites

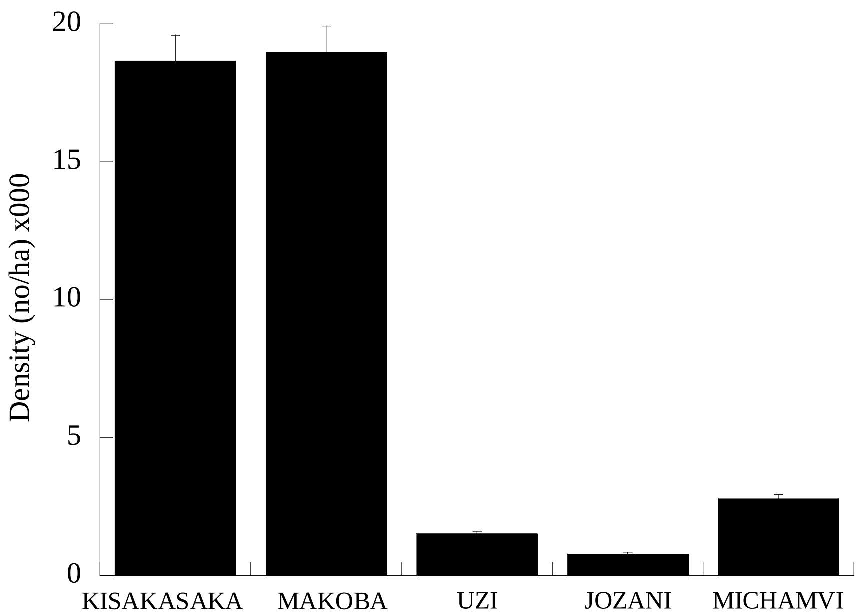

Figure 2. Comparison of tees density (no/ha) between mangrove sites

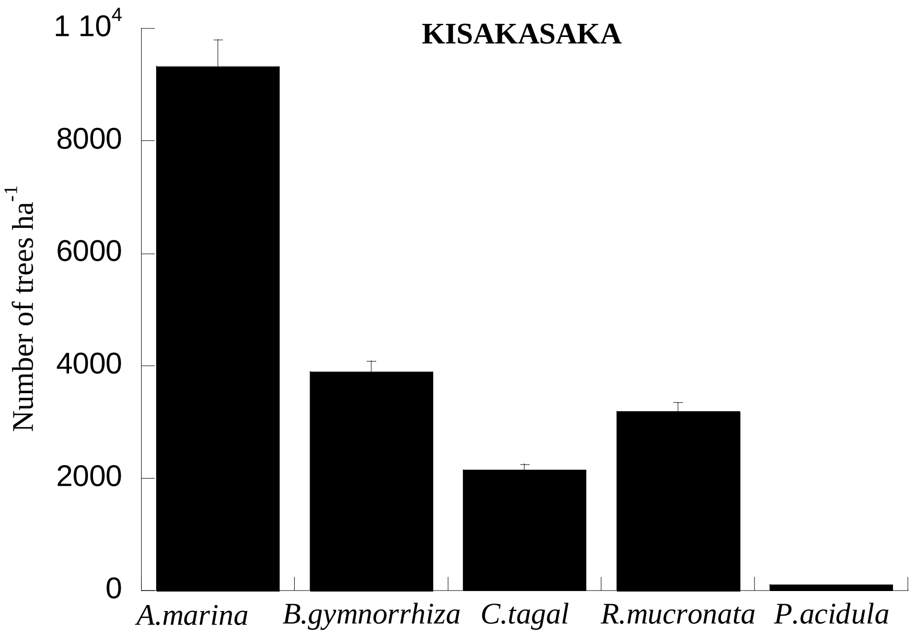

Figure 3. Comparison of regeneration rate between mangrove species at Kisakasaka

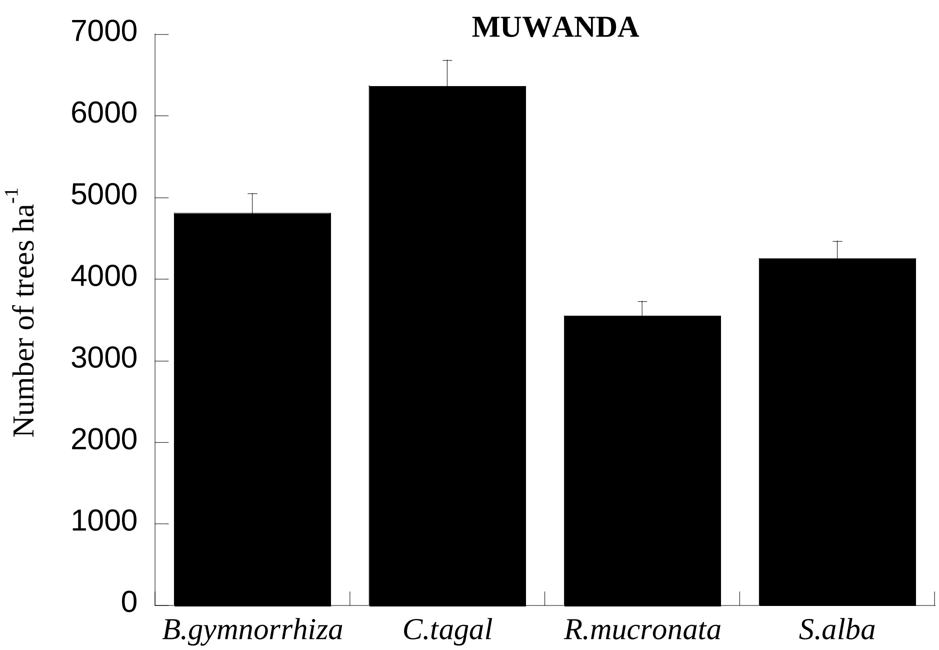

Figure 4. Comparison of regeneration rate between mangrove species at Makoba Bay

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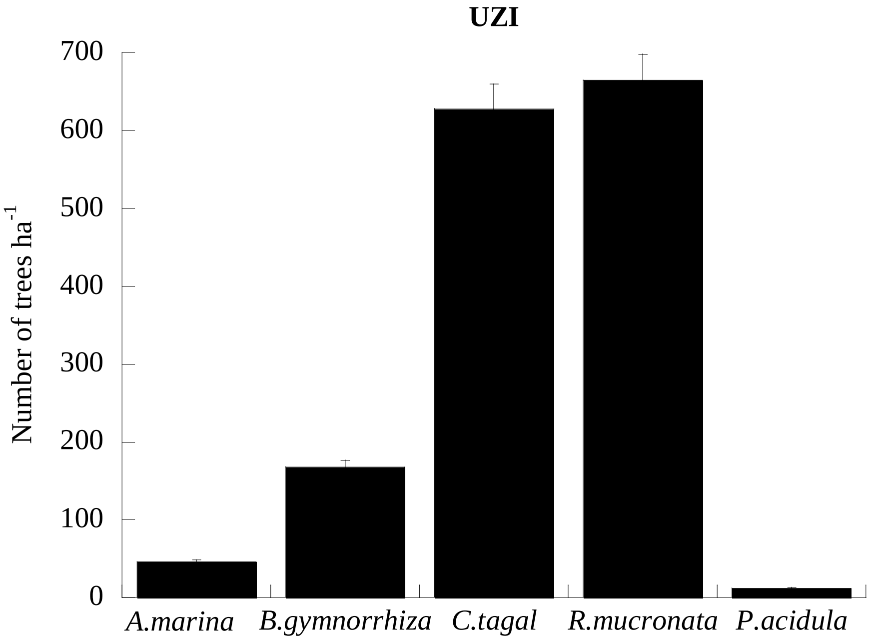

Figure 5. Comparison of regeneration rate between mangrove species at Uzi Island

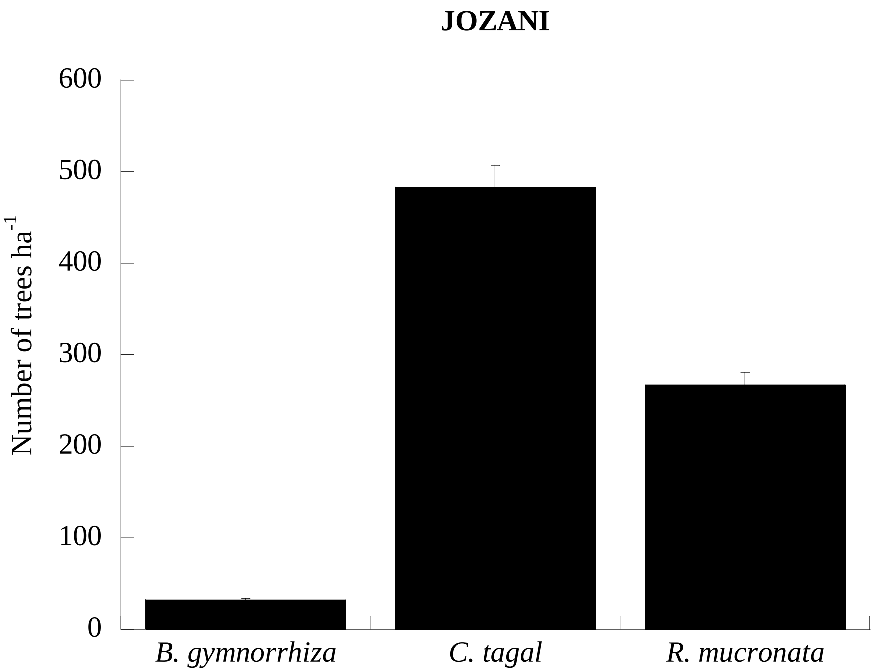

Figure 6. Comparison of regeneration rate between mangrove species at Jozani

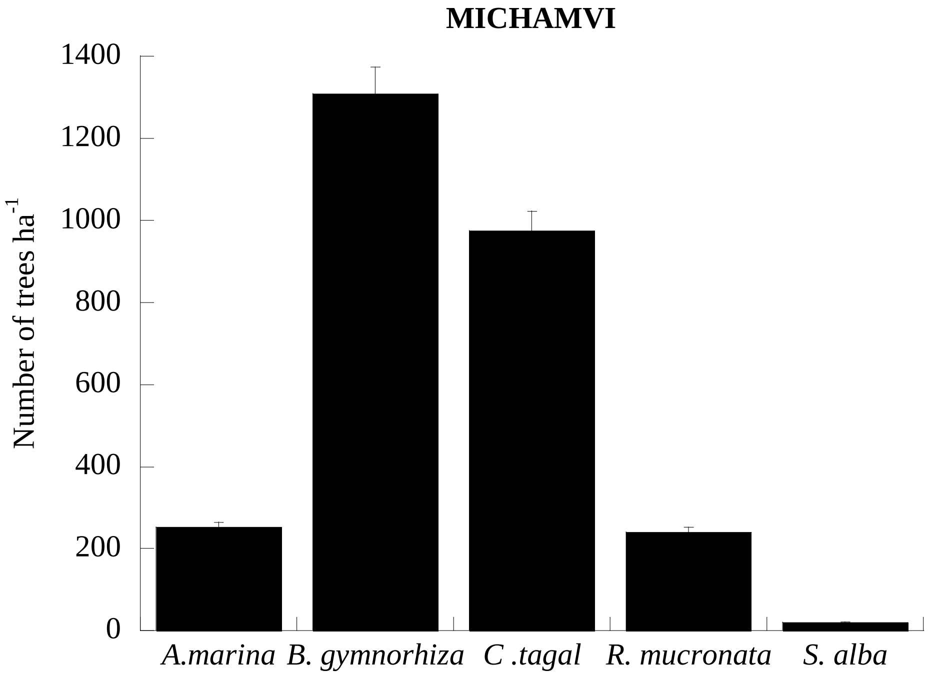

Figure 7. Comparison of regeneration rate between mangrove species at Michamvi

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