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Research Paper

STRUCTURE AND NATURAL REGENERATION OF MANGROVES IN AREAS EXPOSED TO DIFFERENT AGENTS OF DEGRADATION IN KENYA

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Abstract

The structure and regeneration of mangrove forests in three coastal areas of Kenya were investigated in this study. This study assessed species diversity, species distribution and regeneration in the three sites. In Mida Creek mangroves, data were collected within a 10 m x 10 m quadrat sample from two stratum of mangrove type: open canopy mangroves and closed canopy mangroves. At Lamu (Manda Island) and Mwache Creek, belt transect measuring 270 x130 m was established running from hinterland towards the seaward cutting across different mangrove zones. In all the three sites, Diameter at Breast Height (DBH) which is 1.3 m above the ground (where the highest prop-roots reach) was measured using a diameter tape. Tree height was measured using a Laser Ace for each mangrove tree to a minimum diameter of 7cm. Saplings and seedlings were enumerated per species within 3 m x 3 m and 1 m x 1 m subplots respectively laid at the center of the main plot for determination of species regeneration. The result demonstrated higher species richness in Manda (seven mangrove species) followed by Mida creek (five species). *C. tagal* was the most dominant species in Mida creek followed by *R. mucronata* as demonstrated by their frequency. Whereas, in Manda Island, the importance value index revealed that *R. mucronata* dominated species followed by *A. marina*. In Mwache Creek, *R. mucronata* and *A. marina* exhibited high importance value index (223.8, and 159.3). No significant difference was observed in DBH ($p<0.001$; LSD=16.49) and Height ($p>0.432$; LSD=0.6310) among the three sites. However, a significant difference observed in the stem density ($p<0.001$; LSD= 2911) and basal area ($p<0.001$; LSD=38.76) among the sites. Mida had big sized trees compared with Manda and Mwache and hence the mean basal area was high in Mida followed by Mwache and Manda. Seedlings and saplings densities indicated significant different among the sites ($p<0.001$). Mwache exhibited the highest seedling density (70,000 seedlings ha^{-1}) followed by Manda (46,667 seedlings ha^{-1}) while Mida had the least (21,694 seedlings ha^{-1}). Generally, the mangrove forest in the three sites had different structural formation and species composition which could be attributed to the different agents of degradation i.e. overexploitation, oil spillage and siltation and stochastic weather events

associated with climate change. Therefore, understanding the structure and regeneration patterns of the mangroves exposed to different agents of degradation is critical for developing site specific management strategies that enhances and preserves the ecological functionality of mangrove ecosystems.
Key words: Mangroves, regeneration, species, diversity, richness, degradation.

INTRODUCTION

Mangrove forests are complex and most productive ecosystems providing a wide array of ecosystem goods and services [1, 2]. These include; fuel and timber production, protection of shoreline from wave erosion, breeding grounds for fish, pollution amelioration and lime production among others [3]. Anthropogenic activities mainly overexploitation and land conversion means that globally, mangrove cover has reduced by one third in recent years and this destruction continues at a rate of 1-2% per annum [4, 5]. The main causes for this destruction are tree felling, conversion to agriculture, urban development, oil spillage and the construction of aquaculture ponds [6, 7]. Moreover, climate change impacts such as sea level rise, flooding erosion, siltation and sedimentation, fluctuating precipitation and temperatures regimes and associated phenomena like hurricane and cyclones have further compounded pressure on mangrove forests [8, 9, 10, 11].

Mangrove forests in Kenya are not pristine and the area under them is reducing at an alarming rate [12]. The loss is being caused by overexploitation, pollution mainly through oil spills and sewage discharge, conversion to agricultural land, siltation, construction of aquaculture ponds and urban development [13]. In Kenya, it is estimated that the total mangrove coverage in 2010 was 45,590 ha representing a loss of 18% (0.7% yr^{-1}) in a period of 25 years i.e. between 1985 and 2010 [3]. Regarding specific mangrove formations, between 1992 and 2009, Tudor lost 86.9% of the mangrove forest while Mwache lost 45.4% representing very high degradation rates of 5.1 and 2.7% per annum, respectively [12]. In Mida creek, 8.8 ha have been degraded between 1969 and 2010 [14]. Losses of mangrove forests have always been accompanied by the loss of ecosystem services such as coastal protection and the provisioning of juvenile fish habitat, which has serious repercussions for local communities' livelihood support systems [15].

Accurate information on the agents of degradation, actual species composition and stand and regeneration densities is important in management planning and interventions including providing evidences to guide rehabilitation and restoration of degraded sites. Consequently, this study aimed at assessing the forest structure and natural regeneration of mangroves in areas exposed to different agents of degradation in Kenya; overexploitation, oil spillage and siltation and stochastic weather events with a hypothesis that they have different structural formation and regeneration patterns.

MATERIALS AND METHODS

This study was conducted in three mangrove sites Mida Creek, Mwache creek and Manda Island in coastal areas in Kenya (Figure 1). The sites were selected based on agents of degradation: Lamu (Manda Island) mainly degraded through overexploitation, Mwache creek by oil spillage and siltation and Mida creek by stochastic weather events mainly Elnino rain associated with climate change. Mida Creek mangrove forest is located in Kilifi County whereas Mwache creek and Manda Island are located in Mombasa and Lamu Counties respectively. The Mida Creek mangrove area is estimated

to cover 1657.8 ha [16, 14], while Lamu mangrove cover 33,500 ha, while in Mombasa it cover 2,000 ha [17].
[18] reported the presence of seven mangrove species in Mida Creek. Another study [19] in Mida creek confirmed the presence of seven mangrove species in which *C. tagal, R. mucronata* and *A. marina* are the dominant species [14]. In Lamu there are two dominant species of mangroves, these are *R. mucronata and C. tagal* species of mangroves. *A. marina*, *R. mucronata*, *C. tagal* and *S. alba* are the dominant species in Mwache creek [12]
The Mida Creek mangroves are not much affected by firewood extraction but are heavily exploited for building and fencing poles [19]. According to [20], the most significant use of mangroves in Mida Creek is the use of poles for house construction.

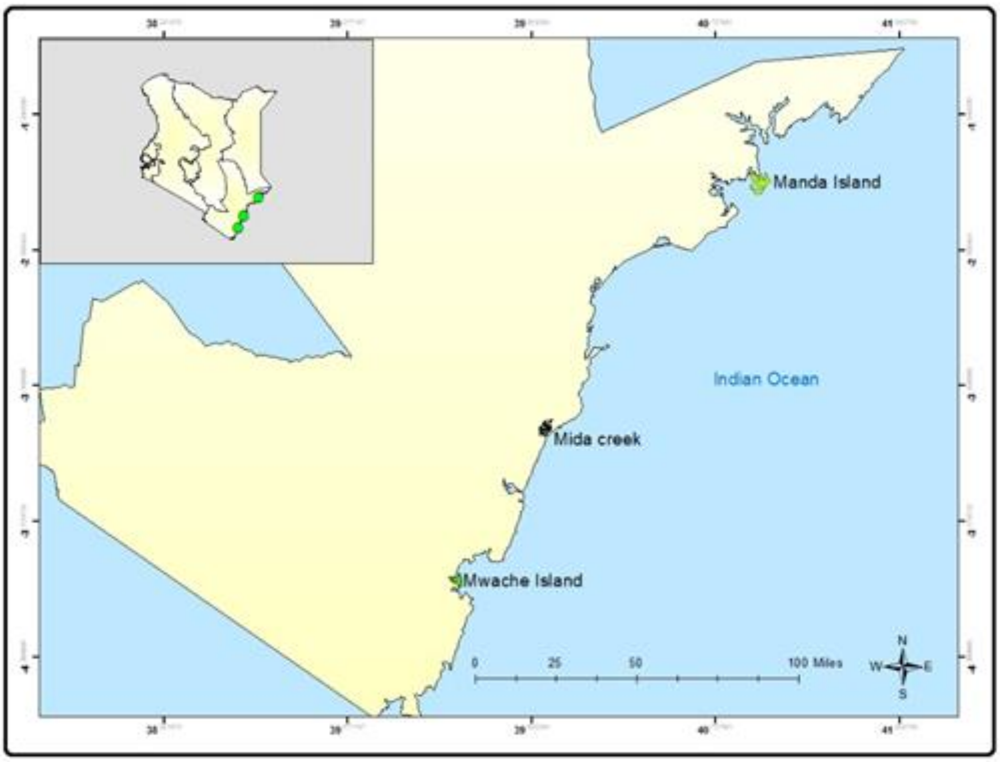

Figure 1: Location Map of the study areas

Data collection
In Mida creek mangrove sites all trees within a 10 m x 10 m quadrat sample were recorded. Using the quadrat, tree measurements were taken in 2013 from the two stratum of mangrove cover type: open canopy mangroves and closed canopy mangroves, both of which occur within the National Reserve. In each stratum, 25 sample plots were randomly distributed on 10 m x 10 m plots. The plots were designed as 10 m x 10 m because the mangrove forest is dense and muddy and difficult for laying sample plots. In each plot tree, Diameter at Breast Height (DBH) which is 1.3 m above the ground (where the highest prop-roots reach) was measured using a diameter tape. Tree height was measured using a Laser Ace for each mangrove tree to a minimum diameter of 7cm. Saplings and seedlings were enumerated per species within 3 m x 3 m and 1 m x 1 m subplots respectively for determination of species regeneration. The subplots were laid at the center of the main plot. The minimum distance between the plots was 50 m.

In Lamu (Manda Island) and Mwache Creek, belt transects measuring 270 x130 m were established running from hinterland towards the seaward cutting across different mangrove zones. The transects was further truncated into three sub-transects at an interval of 120 m taking into cognizance the species zonation. Within each zone/sub-transect, three sample plots measuring 10 x10 m were established systematically at an interval of 50 m. Within the 10 x10 m plots, nested subplots measuring 3 x 3 m and 1 x 1 m were established. Replicate transects were systematically laid at an interval of 500 m. In the 1 x 1 m plot, all seedlings (≤40 cm height) were enumerated by species, while in 3 x 3 m subplots, all saplings (>40 cm≤150 cm height) were enumerated by species. Mature mangrove trees (>150 cm height) were also enumerated by species in 10 x 10 m plot and DBH was measured at 1.3 m above the ground and total height taken. However, for *Rhizophora mucronata*, DBH was measured just above the top prop root. A total of six transects and eighteen plots were studied in Manda Island and Mwache creek while twenty five plots were studied in Mida creek.

Data analysis

The vegetation characteristics and structure of the mangrove forest (relative dominance, density, frequency and importance values) were calculated as follows:

Basal area (m^2) of each species = 0.05 × DBH

Total basal area of all species (m^2/ha) = Sum of all species basal area / total No. of individuals of all species × 100

Relative density = No. of individuals of a species / total No. of individuals of all species × 100

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

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

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

Data was analyzed using GenStat version 16.0. The data collected was subjected to descriptive statistics to obtain mean values for DBH, height, basal area and stem density. Besides, data on DBH, height, basal area and stem density stem was subjected to Two-Way ANOVA to examine the significance differences in these variables among the different mangrove species in the three sites. Log-linear regression was performed to determine the significant difference in seedling and sapling densities. Means that exhibited differences were compared using Tukey's test with a 5% probability significance threshold.

RESULTS

Vegetation characterization and species composition at Manda Island, Mida creek and Mwache Creek

Manda Island had higher species richness, followed by Mida creek (Table 1). A total of seven species were recorded in Manda Island while five species of mangrove observed in Mida creek. Compared with Mida and Manda, only three mangrove species were found along Mwache creek. *C. tagal* was noticed the most dominant species in Mida creek followed by *R. mucronata* as demonstrated by their frequency. In Manda Island, the importance value index revealed that *R. mucronata* dominated species followed by *A. marina*. In Mwache Creek, *R. mucronata* and *A. marina* exhibited high importance value index (223.8, and 159.3) (Table 1) respectively. *B. gymnorrhiza, L. racemose, S. alba* and *Heritiera littoralis* were found not to be growing in Mwache Creek.

Table 1: Comparison of relative dominance, density, frequency and importance value of mangroves in the three study sites

Sites	Species	Dominance	Density	Frequency	Importance value
Mida Creek	*R. mucronata*	27.4	22.8	80	130.2
	C .tagal	57.5	69.3	96	222.8
	B. gymnorrhiza	9.0	3.7	36	48.7
	A. marina	7.4	4.1	32	43.5
	X. granatum	0.1	0.1	4	4.2
Manda	*R. mucronata*	41.6	39.6	100	181.2
	C. tagal	18.8	24.1	100	142.9
	B. gymnorrhiza	2.1	3.4	33.3	38.8
	A. marina	28.9	18.9	100	147.8
	X. granatum	1.3	1.7	33.3	36.3
	S. alba	4.0	3.4	33.3	40.7
	L. racemosa	6.2	6.8	100	112.8
Mwache	*R. mucronata*	57.1	66.7	100	223.8
	C. tagal	6.6	10.4	66.7	83.7
	A. marina	4.4	22.9	100	159.3

Mangrove forest structures in the study sites

There was no significant difference in DBH among the three sites ($p<0.001$; LSD=16.49). Similarly, height was not significantly different among the sites ($p> 0.432$; LSD=0.6310). The stem density was significantly different ($p<0.001$; LSD=2911). There was a significant difference in basal area among the sites ($p<0.001$; LSD=38.76). Generally, Mida had big sized trees than Manda and Mwache and hence the mean basal area was high in Mida followed by Mwache and then Manda (Table 2).

Table 2: Comparison of mean DBH, height and basal area of different mangrove forests in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Sites	DBH (cm)	Height (m)	Stem density (stems/ha)	BAha^{-1} (m^2)
Manda	4.67±0.446	2.956±0.242	2160±668.8	5.02±1.656
Mida	25.36±3.323	3.534±0.245	1505±198.4	61.20±7.668
Mwache	4.40±0.695	3.055±0.254	10350±4351	29.11±11.96

Significance difference existed in stem density among the different mangrove species in all the sites ($p<0.001$; LSD=1305). *C. tagal* had the highest stem density in Manda (4933±919.0) and Mida (4533±919.0) followed by *R. mucronata* which had stem density of 4533±919.0 in Manda and 1060±355.9 in Mida (Table 3). In Mwache, *R. mucronata* had the highest stem density of 24767±919.0 followed by *C. tagal* (2200±1125.5). *X. granatum* had the lowest stem density in Manda and Mida and was absent in Mwache.

Table 3: Comparison of mean stem density of different mangrove species in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Site	Species	Stem density (stems ha^{-1})
Manda	*Avicennia marina*	933±919.0
	Bruguiera gymnorrhiza	200±1591.8
	Ceriops tagal	4933±919.0
	Lumnitzera racemosa	300±1125.5
	Rhizophora mucronata	4533±919.0
	Sonneratia alba	150±1125.5
	Xylocarpus granatum	100±1591.8
Mida	*Avicennia marina*	475±562.8
	Bruguiera gymnorrhiza	389±530.6
	Ceriops tagal	2696±324.9
	Lumnitzera racemosa	-
	Rhizophora mucronata	1060±355.9
	Sonneratia alba	-
	Xylocarpus granatum	100±1591.8
Mwache	*Avicennia marina*	1367±919.0
	Bruguiera gymnorrhiza	-
	Ceriops tagal	2200±1125.5
	Lumnitzera racemosa	-
	Rhizophora mucronata	24767±919.0
	Sonneratia alba	-
	Xylocarpus granatum	-

Generally, there was no significance difference in basal area among the sites (p=0.798; LSD=45.11). However, the basal area varied among species in the three sites. *R. mucronata* had the largest basal area in Manda Island and Mwache creek while *A. marina* had the largest basal area in Mida creek (Table 4).

Table 4: Comparison of mean basal area for different species of mangroves in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Site	Species	Basal area (m^2/ha)
Manda	*Avicennia marina*	5.76±31.77
	Bruguiera gymnorrhiza	0.15±55.02
	Ceriops tagal	4.05±31.77
	Lumnitzera racemosa	0.56±38.91
	Rhizophora mucronata	14.55±31.77
	Sonneratia alba	0.38±38.91
	Xylocarpus granatum	0.10±55.02
Mida	*Avicennia marina*	83.74±19.45
	Bruguiera gymnorrhiza	55.93±18.34
	Ceriops tagal	51.92±11.23
	Lumnitzera racemosa	-
	Rhizophora mucronata	68.70±12.30
	Sonneratia alba	-

	Xylocarpus granatum	1.13±55.02
Mwache	*Avicennia marina*	6.95±31.77
	Bruguiera gymnorrhiza	-
	Ceriops tagal	3.08±38.91
	Lumnitzera racemosa	-
	Rhizophora mucronata	68.61±31.77s
	Sonneratia alba	-
	Xylocarpus granatum	-

There was significance difference in DBH among the species across all the sites (p = 0.027; LSD = 15.46). In Manda, *A. marina* had trees with large diameters (6.0±10.9cm) followed by *S. alba* (5.9±13.3cm) while *B. gymnorrhiza* and *C. tagal* had trees with small diameters (Table 5). Similarly, *A. marina* had big trees with large diameters in Mida and Mwache whereas *C. tagal* had small sized trees in the same two sites.

Table 5: Comparison of mean DBH for different species of mangroves in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Site	Species	DBH (cm)
Manda	*Avicennia marina*	6.0±10.9
	Bruguiera gymnorrhiza	3.1±18.9
	Ceriops tagal	3.1±10.9
	Lumnitzera racemosa	4.4±13.3
	Rhizophora mucronata	5.3±10.9
	Sonneratia alba	5.9±13.3
	Xylocarpus granatum	3.5±18.9
Mida	*Avicennia marina*	66.0±6.7
	Bruguiera gymnorrhiza	30.4±6.3
	Ceriops tagal	14.5±3.9
	Lumnitzera racemosa	-
	Rhizophora mucronata	20.5±4.2
	Sonneratia alba	-
	Xylocarpus granatum	12.0±18.9
Mwache	*Avicennia marina*	5.7±10.9
	Bruguiera gymnorrhiza	-
	Ceriops tagal	3.0±13.3
	Lumnitzera racemosa	-
	Rhizophora mucronata	4.1±10.9
	Sonneratia alba	-
	Xylocarpus granatum	-

There was no significance difference in height among the sites (p=0.624; LSD=1.338). *R. mucronata* and *A. marina* had the tallest trees in all the sites while *L. racemosa* and *C. tagal* had the shortest trees in the sites they occurred (Table 6).

Table 6: Comparison of mean height for different species of mangroves in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Site	Species	Height (m)
Manda	*Avicennia marina*	3.2±0.9
	Bruguiera gymnorrhiza	5.3±1.6
	Ceriops tagal	2.2±0.9
	Lumnitzera racemosa	2.1±1.2
	Rhizophora mucronata	3.4±0.9
	Sonneratia alba	3.0±1.2
	Xylocarpus granatum	2.5±1.6
Mida	*Avicennia marina*	5.3±0.6
	Bruguiera gymnorrhiza	4.2±0.5
	Ceriops tagal	2.8±0.3
	Lumnitzera racemosa	-
	Rhizophora mucronata	3.4±0.4
	Sonneratia alba	-
	Xylocarpus granatum	3.0±1.6
Mwache	*Avicennia marina*	3.3±0.9
	Bruguiera gymnorrhiza	-
	Ceriops tagal	2.3±1.2
	Lumnitzera racemosa	-
	Rhizophora mucronata	3.3±0.9
	Sonneratia alba	-
	Xylocarpus granatum	-

Forest regeneration

Generally, seedlings and saplings densities was significantly different among the sites ($p<0.001$). Mwache exhibited the highest seedling density (70,000 seedlings per hectare) followed by Manda (46,667 seedlings per hectare) while Mida had the least (21,694 seedlings per hectare). A large number of seedlings in Manda and Mwache died before transiting to saplings (Table 7). The massive death of seedlings before growing into saplings hindered effective succession which is important in maintaining a healthy mangrove ecosystem.

Table 7: Comparison of mean seedlings and saplings densities in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Site	Seedlings/ha	Saplings
Manda	46667±21985	8200±3328
Mida	21694±2831	21368±2780
Mwache	70000±30000	4166±1405
P value	*<0.001*	*<0.001*

The sapling density of different mangrove species significantly differed in all the sites (P<0.001) as indicated in Table 8.

Table 8: Estimates of parameters of log linear regression showing significant differences in saplings density for the species in Manda Island, Mida and Mwache creeks

Site	Estimate	S.E.	t-statistic	P value	Antilog of estimate
Manda	9.09246	0.00401	2268.59	<0.001	8888
Mida	9.68894	0.00172	5640.45	<0.001	16138
Mwache	8.55346	0.00567	1508.61	<0.001	5185

A. marina, B. gymnorrhiza, C. tagal and *R. mucronata* had saplings in Manda and Mida while in Mwache only saplings of *A. marina* and *R. mucronata* were found occurring there (Table 9). *C. tagal* had highest sapling density in both Manda and Mida followed by *R. mucronata* while *A. marina* had the least density.

Table 9: Comparison of mean saplings density for different mangrove species in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Site	Species	Saplings per ha
Manda	*Avicennia marina*	1111±0.0
	Bruguiera gymnorrhiza	1111±0.0
	Ceriops tagal	9696±5418
	Rhizophora mucronata	8888±5443
Mida	*Avicennia marina*	3250±1750
	Bruguiera gymnorrhiza	9175±5059
	Ceriops tagal	32441±4766
	Rhizophora mucronata	16138±3180
Mwache	*Avicennia marina*	1111±0
	Bruguiera gymnorrhiza	0±0
	Ceriops tagal	0±0
	Rhizophora mucronata	5185±1689

Log linear regression analysis using Poisson distribution (Table 10) showed that there was a significant difference in seedlings density for all the species in the three sites (P<0.001).

Table 10: Estimates of parameters of log linear regression for showing significant differences in seedlings density for the species in Manda Island, Mida and Mwache creeks

Site	Estimate	S.E.	t-statistic	P value	Antilog of estimate
Manda	9.90349	0.005	1980.7	<0.001	20000
Mida	9.694	0.00176	5521.42	<0.001	16220
Mwache	11.15625	0.00267	4174.29	<0.001	70000

C. tagal had the highest seedlings density in Manda and Mida followed by *R. mucronata* (Table 11). *A. marina* and *B. gymnorrhiza* did have seedlings in Manda and Mwache while *C. tagal* had no seedlings in Mwache. *R. mucronata* was the only species that had seedlings in Mwache.

Table 11: Comparison of mean seedlings density for the different mangrove species in Manda Island, Mida and Mwache creeks. The presented values are means with standard error of mean

Site	Species	Seedlings per ha
Manda	*Avicennia marina*	0±0
	Bruguiera gymnorrhiza	0±0
	Ceriops tagal	54286±27933
	Rhizophora mucronata	20000±10000
Mida	*Avicennia marina*	9400±9100
	Bruguiera gymnorrhiza	7475±4801
	Ceriops tagal	32021±4176
	Rhizophora mucronata	16220±4225
Mwache	*Avicennia marina*	0±0
	Bruguiera gymnorrhiza	0±0
	Ceriops tagal	0±0
	Rhizophora mucronata	70000±30000

DISCUSSION

The overall assessment of the study in Manda Island, Mida and Mwache creeks indicated different levels of forest degradation due to a number of reasons such as proximity to urban areas, selective cutting of a specific mangrove species, overexploitation and the general changing trends of the weather, siltation and oil spillage. A similar comparative study in Tudor and Mwache creeks indicated degradation of mangrove forest as the result of human interference [12]. The same human induced change observed in Mida creek mangrove forest [19] specifically selective cutting mainly for the construction of the booming tourism industry which was also confirmed in the study by [14].

This study also found out that, mangrove stem density of adult trees in the three sites differed from species to species. For example, in Mida, *C. tagal* and *R. mucronata* has higher density of 4933 stems/ha and 4533 stems/ha respectively whereas in Manda *C. tagal* has the higher density of 2696 stems/ha. Mwache has the highest density of *R.*

mucronata which is 24,767 stems/ha. One can observe the dominance of the two mangrove species i.e. *C. tagal* and *R. mucronata*. In addition, the same kind of the dominance of *C. tagal* and *R. mucronata* species observed in the density of sapling in Mida and Manda.

Further, it was also observed that in terms of species richness and diversity, Mwache creek is highly degraded compared to Mida creek and Manda Island. For example, *Bruguiera gymnorrhiza, Lumnitzera racemose, Sonneratia alba* and *Heritiera littoralis* seems to be heavily affected by oil spillage and siltation which are the significant factors driving degradation of mangroves in Mwache Creek. In Mwache a study by [12] revealed the dominance of two species i.e. *R. mucronata and S. alba*. However, the current study showed the dominance of *R. mucronata* and *A. marina* which was exhibited with high importance value index of (223.8, and 159.3) respectively. Another important observation drawn from this study is that *R. mucronata* is less affected by oil spillage and siltation and could be effectively used to rehabilitate and restore sites that are degrading due to the oil spillage and siltation.

In terms of regeneration, Mwache exhibited the highest seedling density (70,000 seedlings per hectare) followed by Manda (46,667 seedlings per hectare) while Mida had the least (21,694 seedlings per hectare). High seedling density is an indication of degradation that has opened up the area leading to system response to recover as exhibited by vigorous regeneration in Mwache creek. A similar study in Zanzibar Island exhibited human induced pressure in the mangrove forest resulted into presence of open spaces which allowed the highest regeneration of mangrove trees and in particular *R. mucronata* [21]. A study in Tudor and Mwache creeks came out with similar result with the current study that high regeneration of mangroves in Mwache as the result of selective wood harvesting [12]. Nonetheless, the presence of sufficient regeneration is encouraging for natural regeneration of the mangrove forest as it was stated in [1] study; a minimum of 2,500 well distributed seedlings are enough for natural regeneration of mangrove forest. All the three sites demonstrated high potential for natural regeneration.

CONCLUSION

In summary, the outcome of the study indicated that oil spillage and siltation immensely affected mangroves leading to high levels of degradation and loss of specific mangrove species in Mwache creek. Moreover, recovery of mangrove forests degraded as a result of oil spillage and siltation is slow and difficult to achieve without human intervention. As earlier stated in this study, massive death of seedlings before growing into saplings hindered effective succession which is important in maintaining a healthy mangrove ecosystem. It was also noted that siltation was the main challenge to successful regeneration of *A. marina* in Mwache creek, a lot of trees had died because of this in the outer zone. Tree felling was observably low in Mwache creek compared to Manda Island. The high demand of mangrove poles for construction that resulted in selective cutting and which in turn creates gaps within the mangroves forest was the main reason of degradation in Mida creek and this has been execerbated by the effects of Elnino rain of 1997-1998 that is associated with climate change.
Compared to other mangrove forest areas in Kenya like Tudor and Kilifi creeks, regeneration of mangroves was high in the three sites with some mangrove species such as *C. tagal* and *R. mucronata* dominating the sites. Regeneration for *R. mucronata* was

high; seeding for the same species was also heavy especially in Mwache creek. Natural regeneration of *Bruguiera gymnorrhiza* was equally high in Manda Island. Further research on the relationship between the agents/drivers of degradation and rate of recovery of degraded mangrove sites after being replanted is recommended in order to develop effective site specific restoration technologies.

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