James Gitundu Kairo, Farid Dahdouh-Guebas, Patrick O. Gwada, Caroline Ochieng and Nico Koedam

Regeneration Status of Mangrove Forests in Mida Creek, Kenya: A Compromised or Secured Future?

The structure and regeneration patterns of Mida Creek mangrove vegetation were studied along belt transects at 2 forest sites of Mida Creek (3°20'S, 40°00'E): Uyombo and Kirepwe. Based on the species importance values, the dominant mangrove tree species in Mida were *Ceriops tagal* (Perr.) C. B. Robinson and *Rhizophora mucronata* Lamk. Tree density varied from 1197 trees ha^{-1} at Kirepwe to 1585 trees ha^{-1} at Uyombo and mean tree height was higher at the former site compared to the latter. The size-class structure at both localities of Mida showed the presence of more small trees than large ones. Spatial distribution pattern of adults and juveniles varied greatly between sites and they showed a close to uniform pattern (Morisita's Index $I_0 << 1$) for trees, but a tendency to random distribution ($I_0 = 1$) for juveniles. The present paper shows that unmanaged but exploited mangroves do not necessarily disappear, but change qualitatively from locally preferred *R. mucronata* to the less preferred *C. tagal*. Whereas the effects of this change on the ecological function of the mangrove cannot be estimated yet, the economical function of the mangrove has evidently weakened.

INTRODUCTION

Mangrove forests in Kenya have traditionally been used as a source of building poles and firewood (1–3). About 70% of the population along the Kenyan coast depend on mangrove poles for house construction (4), and the recent boom in tourism in the area over the last few decades has led to an increasing demand for mangrove poles for construction of restaurants, hotels and holiday resorts (5).

The most harvested mangrove poles are the *mazio* and *boriti* sized poles with butt diameter ranging from 8.0 to 13 cm. These are used in construction (2, 3, 6). Larger poles of *banaa* (diameter above 30.5 cm) are of less economic value and are left standing in the forest (3, 7, 8). Excessive removal of *boriti* and *mazio* poles has created complex mangrove management problems in Kenya along the whole coast (3, 5, 6). The overgrowing *banaa* canopy shade out juveniles and young trees and cause them to be crooked, as they grow according to available space in the closed forest canopy (9).

In order to achieve sustainable forest management there is a need to assess the trends in forest conditions over time. One way to characterize mangrove ecosystem, and to monitor changes is through the assessment of forest structure (10, 11), these aspects being closely linked to forest productivity (12). Some of the structural parameters used are: tree height, stem diameter, basal area, crown diameter and leaf area index (11, 13), from which other attributes like stand tables, regeneration rates, distribution patterns and complexity index can be derived. Structural studies have been used to describe the mangroves of Puerto Rico (14), and mangrove stands in Florida, Mexico and Costa Rica (15) among others.

Past studies on mangrove forestry in Kenya tend to have concentrated on floristic composition and distribution of species (16–18), economic utilization (2, 3) and regeneration strategies of the principal species (6, 19). Work on mangrove benthos has yielded results regarding resource partitioning (20), zonation (21, 22), feeding habits and propagule predation (23–26). Studies on nutrient cycling have also been carried out (27, 28). Quantitative data on mangrove vegetation structure, stocking rates and yield sustainability is lacking, an aspect which has been much neglected until recently for want of resources and personnel.

The main objective of the present study was to investigate natural regeneration and timber potential of the mangrove forests of Mida Creek for better management, based on the principle of sustained yield.

DESCRIPTION OF THE STUDY SITE

Mida Creek or Watamu Marine National Reserve (3°20'S, 40°00'E) is situated 100 km north of Mombasa in Kilifi district. The reserve was established in 1968, contains natural elements such as mangroves, coral reefs, and mud flats and is a sanctuary for shorebird populations (29). Seven of the 9 mangrove species described in Kenya (2) are found in Mida, and occupy a total area of 1746 ha (30, 31). The dominant species are *Rhizophora mucronata* Lamk. (Rhizophoraceae), Ceriops tagal (Perr.) C.B. Robinson (Rhizophoraceae) and *Avicennia marina* (Forsk.) Vierh. (Avicenniaceae). The nomenclature is according to Tomlinson (32).

There is no obvious zonation that is displayed by the dominant mangrove species in Mida. *A. marina and Lumnitzera racemosa* Willd. occupy the landward zone, whereas mostly a *C. tagal* and *R. mucronata* mosaic covers the middle zone. Wherever present, *Sonneratia alba* Sm. occupies the seaward margin, but is replaced by tall *A. marina* and *R. mucronata* along small creeks.

The mangroves of Mida Creek are separated naturally by the main creek and the 2 areas are named according to the nearby local villages or islands : Kirepwe and Uyombo (Fig. 1). In the framework of this study these 2 areas were sampled separately and compared. Kirepwe covers the eastern side of the creek and includes mangroves near the villages of Sita, Dabaso and Dongokundu. In the area of the forest approaching Sita seaward (Fig. 1), trees attained a height of 20 m and diameters above 18 cm. There are 573 ha of mangroves in Kirepwe. Uyombo, on the western side of the creek, stretches between the villages of Uyombo and Majaoni. Because of a large intertidal area, there is a marked difference in the vegetation structure of the seaward and the landward forest in Uyombo (*cf.* 22). The landward forest is mostly dwarf *A. marina* while the seaward forests consists of tall *R. mucronata*. The total mangrove cover in Uyombo is 1172 ha.

The floristic composition of mangroves of Mida has been described by Gang and Agatsiva (30). The forest resembles the fringing mangroves described by Lugo and Snedaker (33), with incoming and retreating tidal velocities that are low and the dense, well-developed prop roots that accumulate large stocks of debris. The forest plays an important role as life support for the Watamu Marine National Reserve (34). This is in addition to the profound ecological benefits reportedly derived from mangroves such as coastal stabilization (35), filtration of land runoff and flood control (36).

MATERIALS AND METHODS

A stratified sampling technique was used to sample mangroves of Mida. The locations of transect lines were determined by an initial reconnaissance and examination of medium-scale (1:25 000) panchromatic aerial photographs of the survey area. Belt transects of 10-m width were established both perpendicular and parallel to the creek across the entire forest, in such a way that they represented as good as possible the general mangrove forest of Mida (Fig. 1). Vegetation sampling was carried out within 100 m^2 quadrats, that were regularly laid along the transects. A total of 60 quadrats were studied in Uyombo and 31 in Kirepwe.

Within each quadrat individual trees greater than 2.5 cm butt diameter were identified and counted. Vegetation measurements included tree height and stem diameter at 130 cm aboveground (D_{130} sensu Brokaw and Thompson, 37), exceptions to this rule are described below, from which were derived tree basal area, species density and frequency (11, 38). The ecological importance of each species (39) was calculated by summing its relative density, relative frequency and relative dominance (11). The complexity indices of the forests (in a 0.1 ha plot) were obtained as the product of number of species, basal area (m^2/0.1 ha), maximum tree height (m) and number of stems/0.1 ha, x 10^{-3} (10). Stems with diameters below 2.5 cm were considered in the category "juveniles".

Tree heights were measured in meters using a Suunto™ hypsometer, whereas stem diameter was measured in centimeters using a forest calliper. For *Rhizophora*, stem diameters were measured 30 cm above the highest prop roots, whereas for *Avicennia*, when the stem forked below 130 cm, individual 'branches' in a clump were treated as separate stems. A total of 6275 m^2 (in 60 quadrats) and 3100 m^2 (in 31 quadrats) were sampled in Uyombo and Kirepwe, respectively.

Information on the composition and distribution pattern of natural regeneration was obtained using the method of Linear Regeneration Sampling (40). In 5 x 5 m^2 subplots (within the main 10 x 10 m^2 quadrats), occurrence of juveniles of different species was recorded and grouped according to their height classes. Seedlings less than 40 cm 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 1.5 m but less than 3.0 m.

The analysis of spatial pattern of trees and juveniles in the field was carried out inside 10 x 10 m^2 plots along transects. The measure of dispersion used was Morisita's Index (41), the application of which is described in Greig-Smith (42). Morisita's Index I_o is:

$$I_o = q\sum_{i=1}^{q} \frac{n_i(n_i-1)}{N(N-1)}$$

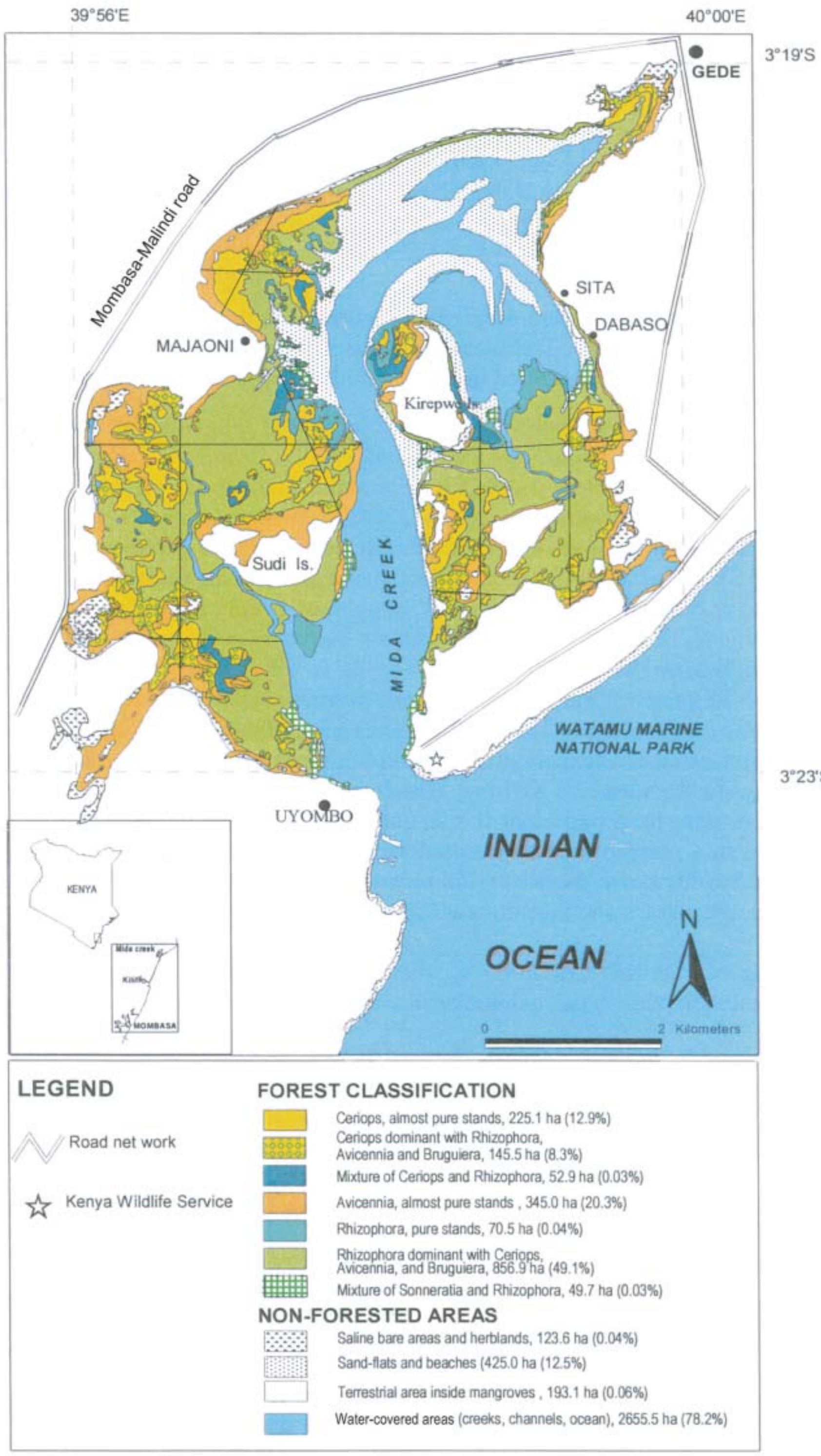
Where, q is the number of quadrats, n_i is the number of individuals per species in the ith plot, and N is the total number of individuals in all q quadrats. If $I_o > 1$, the population is clustered, if $I_o = 1$, the population is randomly dispersed and if $I_o < 1$, the population is evenly dispersed.

DATA TREATMENT

All data analysis and graphical presentation were obtained with the IBM compatible STATISTICA 5.5 program. One-way ANOVA was performed on stocking densities of different size classes, which we assume as a measure of age.

The stand densities were harmonized using De Liocourt's negative exponential model (43). According to the model, the

Figure 1. Vegetation map of Mida Creek, based on aerial photography and ground truthing. The straight black lines across the vegetation show the position of the belt transects. The legend shows the spatial quantification of the image objects. Quantification of the vegetation based on ground truth data is indicated in Tables 1 to 4.



ratio between the numbers of trees in successive diameter classes of uneven-aged stand is roughly constant for a particular forest, but varies from one forest to another. This has been confirmed in a number of uneven-aged forests throughout the world (see e.g. 43 and the literature therein). De Liocourt's model applies particularly in mixed forests where the size classes and recruitment by natural regeneration are continuous.

Supposing we take this ratio to be q, then the number of trees in successive diameter classes is represented by a descending geometric sequence of the form:

$aq^n, aq^{n-1}, aq^{n-2}, aq^{n-3}, ...aq^3, aq^2, aq^1, a$

where a is the number of trees in the largest size class of interest and n is the number of classes.

For such a geometric series, if the logarithm of the frequency in successive classes is plotted against size class, the distribution can be represented as an exponential curve of the form:

$y = ke^{-ax}$

where; y is the number of trees in diameter class x; e is the base of natural log (2.718) while k and a are constants.

The constants k and a in the equation above vary between forests and with site. Constant k reflects the occurrence of seedling regeneration and tends to be large in forests containing prolific seed-bearing tree species while a determines the relative frequencies of successive diameter classes . A high a is associated with high mortality between classes and is likely to occur in stands comprising light demanding (shade intolerant) tree species.

The nature of the future forest was derived from the present forest by fitting exponential models to the size-class structures and comparing the results at a 0.05 significant level. Each class interval was considered to be independent and thus included as within-factor repeated measure variable during the analysis. A chi-square test was used to analyze differences in juvenile densities among the study sites.

Table 1. Importance Values (I.V.) of the mangroves of Mida Creek, Kenya.

Forest block	Species	Dominance	Relative values (%) Density	Frequency	I.V.
Uyombo	*R. mucronata*	64.77	27.36	61.67	153.80
	C. tagal	37.61	56.74	78.33	172.68
	A. marina	34.47	11.97	21.67	68.11
	B. gymnorrhiza	20.48	3.33	30.00	53.81
	X. granatum	1.26	0.30	1.67	2.23
	L. racemosa	0.91	0.30	1.67	2.88
Kirepwe	*R. mucronata*	40.97	45.55	74.19	160.71
	C. tagal	12.89	33.42	83.87	130.18
	A. marina	19.66	11.59	29.03	60.28
	B. gymnorrhiza	20.90	7.01	38.71	66.62
	X. granatum	1.42	0.81	6.45	8.68
	S. alba	4.14	1.62	2.23	7.99

(Total number of plots: Uyombo = 60 (total area = 6275 m^2), Kirepwe = 31 (total area = 3100 m^2). Number of individuals encountered: Uyombo = 994, Kirepwe = 331).

RESULTS

Floristic Composition

Table 1 shows the composition of mangrove forests in Mida. Based on the species' importance values, *R. mucronata* and *C. tagal* were the principle species at Uyombo and Kirepwe, respectively. Relative dominance, density, frequency and importance values of these species are shown in Table 1.

Stocking Density

Table 2 give vegetation inventories for Mida Creek mangroves. There were 1585 stems ha^{-1} of mangroves in Uyombo, out of

Table 2. Stand table for the mangrove forest of Mida Creek. Values in parentheses indicate percentages of the total in a column.

Station	Species	Utilization class (butt diameter in cm) ≤ 6.0	6.1–9.0	9.1–13.0	13.1–20.0	20.1–35.0	> 35.0	Density (Stems ha^{-1})
Uyombo	*A. mar*	61	28	37	45	16	3	190
		(32.11)	(14.74)	(19.47)	(23.68)	(8.42)	(1.58)	(11.99)
	B. gym	17	3	2	10	18	3	53
		(32.08)	(5.66)	(3.77)	(18.87)	(33.96)	(5.66)	(3.34)
	C. tag	682	93	76	46	2	–	899
		(75.86)	(10.34)	(8.45)	(5.12)	(0.22)		(56.72)
	L. rac	–	–	3	2	–	–	5
				(60.00)	(40.00)			(0.32)
	R. muc	135	81	76	100	38	2	433
		(31.18)	(18.71)	(17.78)	(23.09)	(8.98)	(0.46)	(27.32)
	X. gra	–	2	–	1	2	–	5
			(40.00)		(20.00)		(40.00)	(0.32)
	Total	**895**	**207**	**195**	**204**	**76**	**8**	**1,585**
		(56.47)	**(13.06)**	**(12.30)**	**(12.87)**	**(4.80)**	**(0.51)**	
Kirepwe	*A. mar*	6	17	16	56	35	6	139
		(4.32)	(13.67)	(12.23)	(40.29)	(25.18)	(4.32)	(11.61)
	B. gym	16	13	3	16	26	10	84
		(19.05)	(15.48)	(3.57)	(19.05)	(30.95)	(11.90)	(7.02)
	C. tag	219	55	48	65	10	3	400
		(54.75)	(13.75)	(12.00)	(16.25)	(2.50)	(0.75)	(33.42)
	R. muc	126	26	90	239	65	–	545
		(23.08)	(4.76)	(16.48)	(43.77)	(11.90)		(45.53)
	S. alb	–	–	–	3	16	–	19
					(15.79)	(84.21)		(1.59)
	X. gra	–	–	–	6	3	–	10
					(66.67)	(33.33)		(0.84)
	Total	**367**	**113**	**158**	**385**	**155**	**19**	**1,197**
		(30.66)	**(9.44)**	**(13.20)**	**(32.16)**	**(12.95)**	**(1.59)**	

A. mar = Avicennia marina; B. gym = Bruguiera gymnorrhiza; C. tag = Ceriops tagal; L. rac = Lumnitzera racemosa; R. muc = Rhizophora mucronata; S. alb = Sonneratia alba; X. gra = Xylocarpus granatum
Total number of plots: Uyombo = 60, Kirepwe = 31; number of individuals encountered: Uyombo = 994, Kirepwe = 331.

which 56.7% were *Ceriops* and 27.3% *Rhizophora*. The rest comprised *Avicennia* (12.0%), *Bruguiera* (3.3%), *Lumnitzera* (0.3%) and *Xylocarpus granatum* König (0.3%). Stem density in Kirepwe was 1197 individuals ha^{-1} (Table 2). The variation in complexity index between Uyombo and Kirepwe is evident (Table 3). Complexity indices were higher in Uyombo than Kirepwe for stems less than 10 cm diameter.

Figure 2 shows scattergrams of heights against stem diameters of mangrove forests in Mida Creek. There was a significant difference in height ($F_{(1,1363)} = 291.1$; $p = 0.0001$) and stem diameter ($F_{(1,1363)} = 120.3$; $p = 0.0001$) between Kirepwe and Uyombo mangroves. Fifty percent (50%) of the *Rhizophora* in Kirepwe had a stem diameter of 12.0–20.0 cm (height: 7.5–13.0 m). Though Kirepwe station had more straight poles than Uyombo, the general quality of the standing wood quantity in the two locations did not show a significant difference ($F_{(1,1364)} = 1{,}017$; $p = 0.3135$.

Forest Revegetation

There were large differences between quadrats in the densities and sizes of juveniles (Table 4). However, based on the total number of saplings, there was no significant difference ($F_{(1,163;\ \alpha = 0.05)}$, $p > 0.05$) in the density of juveniles between Uyombo and Kirepwe (Fig. 3). The densities of established juveniles (RCII

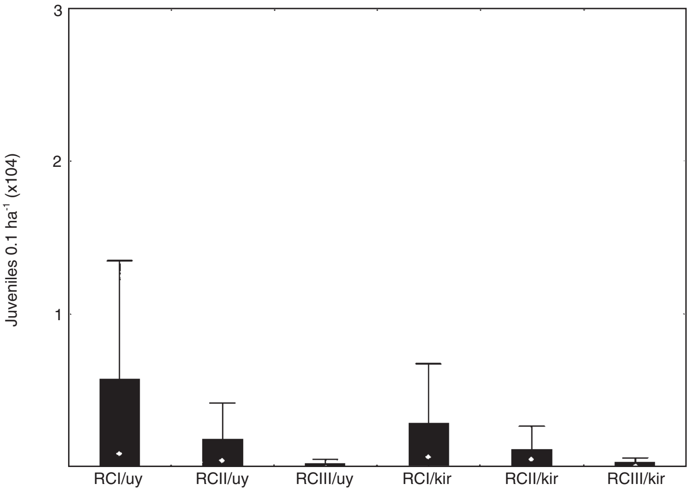


Figure 3. Box-plot display of mangrove saplings in Uyombo (uy) and Kirepwe (kir) stations of Mida Creek. The ends of the box are positioned at the 75% percentiles of the data set.

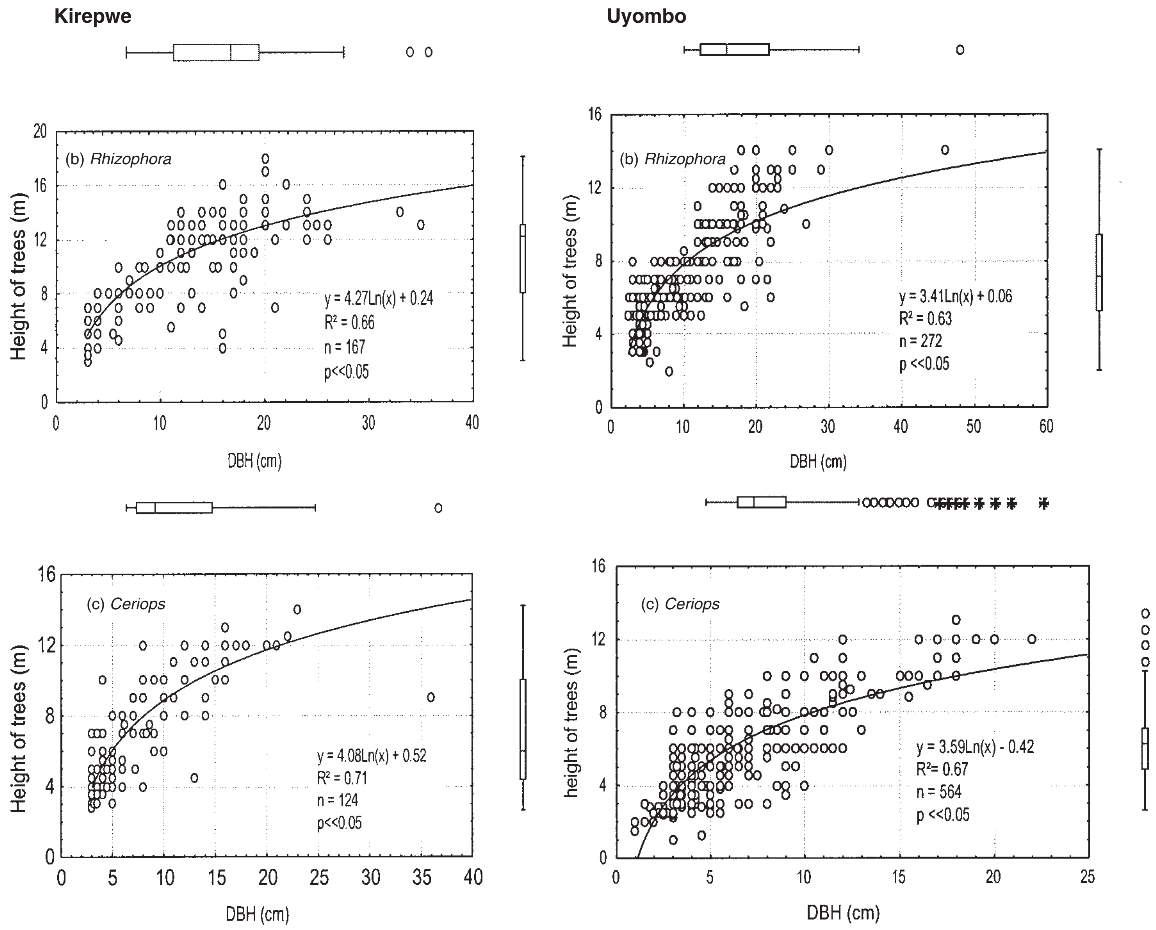


Figure 2. Height-diameter distribution of mangrove forests in Mida Creek: (b) *Rhizophora*, and (c) *Ceriops*. The box-plots display percentile distribution in each case. The extremities of the plot correspond to the maximum and minimum observed values in the data set. The ends of the boxes are positioned at the 25% and 75% percentiles of the data set.

Table 3. Summary of the structural characteristics of Mida mangroves.

Station	Uyombo				Kirepwe			
Diameter class (cm)	< 5	5–10	10–15	> 15	< 5	5–10	10–15	> 15
3. No. of species	4	5	5	6	4	4	5	6
4. Stem density ha^{-1}	777	373	195	234	290	226	216	465
5. Mean height (m)	4.3	6.2	8.1	10.4	5	7.6	10.8	12.1
6. Basal area (m^2 ha^{-1})	0.89	1.70	2.38	10.87	0.33	1.04	2.85	19.40
7. Complexity Index *	0.12	0.20	0.19	1.59	0.02	0.07	0.33	6.55

* The complexity index C.I. equals the product of (3), (4), (5) and (6) divided by 10^5 (10).

and RCIII) were 50 158 and 22 723 saplings ha^{-1} in Uyombo and Kirepwe, respectively (Table 4). Most of the juveniles in Uyombo (85.4%) and Kirepwe (51.4%) were *Ceriops*. Examination of dispersion pattern showed a close to uniform patterns ($I_0 << 1$) of adult trees but a tendency to random distribution ($I_0 = 1$) for juveniles (Fig. 4).

DISCUSSION

Mangrove forests in Mida Creek are not pristine. All sites visited during this study had visibly been subjected to human disturbance of varying magnitude, over the last 20–30 years (1). These activities have an accumulated effect on the current structure and regeneration of the forest. The high complexity index recorded in the mangrove forests of Kirepwe indicate especially the high basal area and canopy height in Kirepwe forests as compared to Uyombo (Table 3). The variation in complexity indices between the 2 locations can also be argued in the light of human pressure. The close proximity of human settlements to mangroves of Uyombo, and the fact that people from across the creek travel to this area to cut trees (3), results in higher consumptive wood extraction from the forest, which in turn is reflected in diminished mangrove poles of *mazio* and *boriti* sizes (butt diameter range: 8.0–13 cm) (Fig. 2). In the less accessible areas of Uyombo, however, there were more stems in the larger diameter classes, taller vegetation and a higher stem density (31).

The structural characteristics of Mida mangroves are given in Table 2. One observation that could be deduced from the stand table data is that stand density is lower for large trees, which is to be expected. However, the relation is not straightforward and when put into size-frequency diagrams it is not possible to obtain a simple correlation between the factors (Fig. 5). This is an indication of man-induced pressure in the forest. Theoretically, in an uneven-aged forest there is a normal series of age-gradations, depicted by the reversed J-curve. The fact that such a relationship was not obvious in some stands of Mida could be indicative for a human influenced environment and the normal relationship is disturbed. It also indicates that the disturbance of the forest is according to direct needs by the people without a particular harvesting plan and therefore the spatial distribution of different size classes becomes haphazard, whereas the graphical frequency distribution becomes highly selective. This is in line with the statements that local people give when interviewed about their harvesting practices (3). On

Table 4. Juvenile density (saplings ha^{-1}) in Mida Creek. Values in parentheses indicate percentages.

Station	Species	Regeneration classes RCI 0–40 cm	RCII 40.1–150.0 cm	RCIII 150.1–300 cm	Total ha^{-1}
Uyombo	*A. marina*	15 751 (952.0* (95.1)	806 (47.0 (4.9)	5 ± 0.6 (0.0)	16 562 (7.1)
	B. gymnorrhiza	2155 (63.1 (78.2)	510 ± 14.7 (18.5)	92 ± 3.3 (3.3)	2757 (1.2)
	C. tagal	155 192 ± 753.1 (77.2)	43 946 ± 383.3 (22.4)	728 ± 3.3 (0.4)	199 866 (85.6)
	L. racemosa	–	–	2 (100)	2 (0.0)
	R. mucronata	10 346 ± 54.6 (71.8)	3924 ± 20.7 (27.2)	145 ± 0.8 (1.0)	14 315 (6.1)
	Total	**183 344 (78.5)**	**49 186 (21.1)**	**972 (0.4)**	**233 502**
Kirepwe	*A. marina*	903 ± 1,223.0 (85.3)	155 ± 14.7 (14.7)	–	1058 (1.1)
	B. gymnorrhiza	426 ± 39.1 (88.6)	39 ± 5.2 (8.1)	16 ± 3.2 (3.3)	481 (0.5)
	C. tagal	38 848 ± 611.4 (75.5)	11 819 ± 143.2 (23.0)	768 ± 15.9 (1.5)	51 435 (51.4)
	R. mucronata	37 223 ± 668.4 (79.0)	9465 ± 143.4 (20.1)	461 ± 5.4 (1.0)	47 149 (47.1)
	Total	**77 400 (77.3)**	**21 478 (24.5)**	**1245 (1.2)**	**100 123**

*mean ± s.d

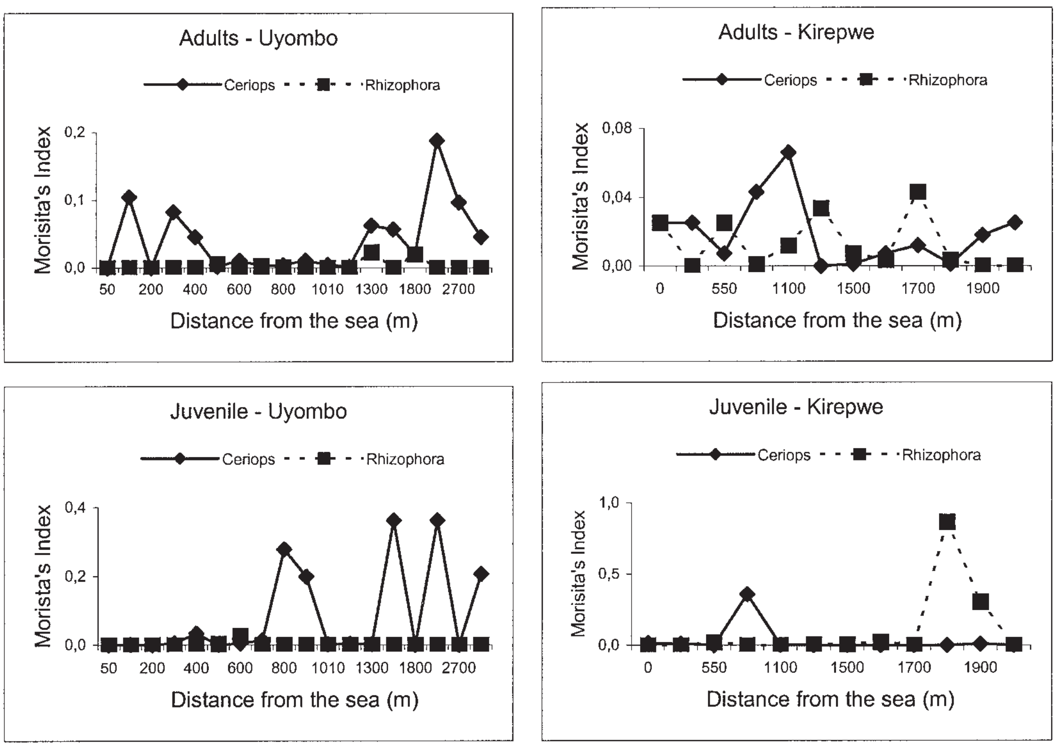


Figure 4. Values of Morisita's Indices along transects for the commercial mangrove species in Mida Creek. Both the adult trees and juveniles are evenly dispersed, $I_0 < 0$.

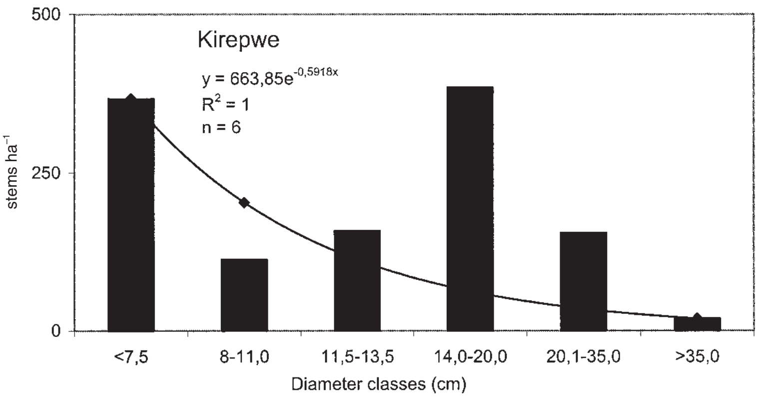
the general assumption that the sizes of trees express age, we can use the density curves obtained in this study (Fig. 5) to predict the composition of the future managed forest. This can be done through 2 approaches. Firstly, we must harmonise the irregularities in the size-class distribution, and the second step will be to reduce stem density per class by allowing multiple use of mangrove wood, e.g. for charcoal or fuelwood production. The present mangrove management in Kenya prohibits the use of mangrove wood products for industrial fuelwood or charcoal, but the question remains to what extent the law is enforced. Dahdouh-Guebas et al. (3) illustrated how vicious the situation may be under a governmental ban to cut mangrove wood. A number of alternatives to mangrove cutting have been suggested (44), but it seems that people receive few alternatives in return from the government.

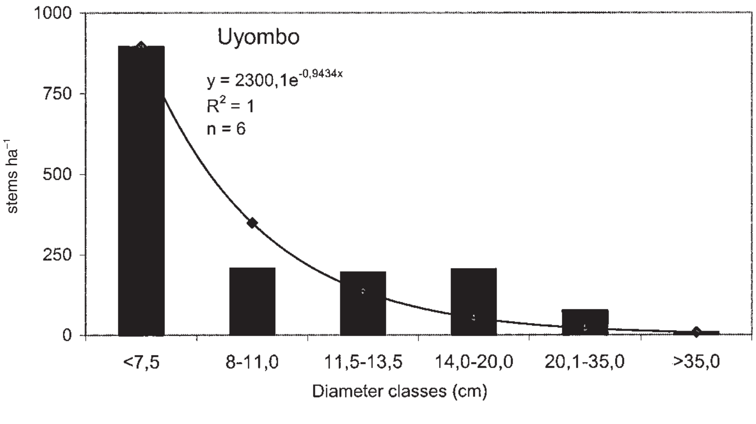
A forest managed on clearcutting silviculture practices and a sustained annual yields basis assumes a normal distribution of size and classes (45). The forest in Mida is akin to that of a selection forest (46). Selective removal of the small-sized poles by the cutters and the consequential creation of gaps in the forest canopy stimulate regeneration that approximates selection forest working. However, this natural regeneration is not necessarily of the same species harvested. Field observation showed that, in a mixed stand of *Ceriops* and *Rhizophora* there was a tendency for natural regeneration to favor *Ceriops*, irrespective of the harvested crop.

The observed pattern can be illustrated with respect to the ratios of adult and young trees (RCIII) of *R. mucronata* and *C. tagal* which is important to highlight (Table 3 and 4). In Uyombo, the site that has been under a stronger anthropogenic influence, the density of adult trees is higher for *Ceriops* than for *Rhizophora* (899 stems ha^{-1} and 433 stems ha^{-1}, respectively) and the same is true for the RCIII young trees (728 *Ceriops* ha^{-1} compared to 145 *Rhizophora* ha^{-1}). In Kirepwe, the *Rhizophora* dominated forest natural to Mida Creek can still be observed in the ratio of the adult trees (545 *Rhizophora* ha^{-1} compared to 145 *Ceriops* ha^{-1}), but the young mangrove population has already shifted to a domination by *Ceriops* (768 *Ceriops* ha^{-1} compared to 461 *Rhizophora* ha^{-1}). Although we cannot estimate what proportion of the young *Ceriops* trees will survive, we are dealing with a regeneration class that may be indicative for a transition in the Kirepwe area, similarly to the one that occurred in the Uyombo area.

This adds to silviculture problems because the desirable *Rhizophora* forest is slowly giving way to the inferior *Ceriops* forest from the local economical point of view (6). Whether the *Ceriops* forest maintains its position in further development or succession, and whether it will play the same ecological role, cannot be assessed with the current data.

Figure 5. Size class distribution of mangrove forests in Mida Creek. A high 'k' value in the stand curve $y = ke^{-ax}$ for Uyombo reflects the occurrence of sporadic natural regeneration in the forest.





CONCLUSIONS

The potential yield of future mangrove forest in Mida can be gauged by an evaluation of the present stand tables. The present inventory revealed that the existing mangrove forests in Uyombo and Kirepwe have standing densities of 1585 and 1197 stems ha^{-1}, respectively (Table 2). This is considered to be high, considering that mangroves of Mida are not pristine. In Matang, Malaysia, the average density for a 30-yr old stand of *R. apiculata* is 1343 trees ha^{-1} with an average volume of 153 m^3 ha^{-1} (47). In Ranong, Indonesia, where some of the best-managed mangroves in the world are located, an average density of 812 trees ha^{-1} and a volume of 226 m^3 ha^{-1} have been reported (48). Chong (45) estimated an annual harvest of 1185 m^3 yr^{-1} in a 25-yr rotation from Térraba-Sierpe of Costa Rica that contained a stocking of 769 trees ha^{-1} (or 281 m^3 ha^{-1}). Mida Creek has probably one of the most productive mangrove forests in Kenya.

The sapling density varied greatly between localities but was on average very high, which implies adequate recruitment in most localities (Table 4). The near randomness of the sapling population may be the result of redistribution of propagules by tidal action (19, 49), which either means that everywhere the right (initial) ecological conditions for the species occur, or that the ecological settings are irrelevant. To assess effective stocking all regeneration classes must be considered. Saplings of RCII/III have higher incremental volume, older mortality, lower mortality, and contribute more significantly towards final crop stocking (46). While working on mangroves of Costa Rica, Chong (45) formulated 'equivalent regeneration values' for different regeneration classes (RCI: RCII: RCIII). A regeneration ratio of 6:3:1 was found to be an effective stocking rate for saplings. In the present study, the 'equivalent regeneration values' for Uyombo and Kirepwe were calculated as 86:51:1 and 62:17:1, respectively. If the management objectives for the mangrove of Mida Creek is to have a dense forest cover (> 60%), irrespective of species, then there will be no need to replant degraded mangrove, areas since the present study shows that Mida's mangrove can recover itself. However, if the management objective is to promote sustainable production of the economically superior *Rhizophora*, the sacrificial removal of excess *Ceriops* may be necessary.

The major outcome of this paper is that unmanaged but exploited mangroves do not necessarily disappear, but change qualitatively as described above. It indicates that small human communities themselves apparently do not sustainably manage the mangrove. The effects of the shifts in dominant species on the ecological function of the mangrove cannot be estimated yet, but the economical function of the mangrove has thus evidently weakened.

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James Gitundu Kairo received a MSc in botany from the University of Nairobi, Kenya and a PhD in sciences from the Vrije Universiteit Brussel, Belgium. He has been working at the Kenya Marine and Fisheries Research Institute for more than 10 years, and is involved in mangrove regeneration and restoration projects for the Kenyan Forestry Department, Word Wide Fund for Nature (WWF), Food and Agricultural Organisation (FAO), and many more. His address: Mangrove System Information Service, Kenya Marine and Fisheries Research Institute (KMFRI), P.O. Box 81651, Mombasa, Kenya. E-mail: jkairo@recoscix.org

Farid Dahdouh-Guebas holds an MSc biology, an MSc human ecology and a PhD sciences from the Vrije Universiteit Brussel. His previous and current research is on tropical coastal ecosystems and includes remote sensing of seagrass distributions, feeding ecology and behavioral ecology of mangrove crabs and ongoing research on mangrove vegetation structure dynamics (using very high resolution remote sensing) and biocomplexity (incl. human factors). His address: Laboratory of General Botany and Nature Management, Mangrove Management Group, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussel, Belgium. E-mail: fdahdouh@vub.ac.be

Patrick O. Gwada is a senior research scientist at the Kenya Marine and Fisheries Research Institute, Mombasa, as well as the Kenyan Coordinator of the Western Indian Ocean Marine Scientists Association (WIOMSA). He holds a MSc from the University of Ryukyus, Japan, where he specialized in mangrove research. He is currently involved in the coordination of the Seaweed Africa Project *Underpinning Sustainable Ecosystem Management of Seaweed Resources in Africa*, an EU research project aimed at expanding the applications of the Seaweed Database. His address: Kenya Marine and Fisheries Research Institute (KMFRI), P.O. Box 81651, Mombasa, Kenya. E-mail: pgwada@recoscix.org

Caroline Ochieng has worked as a research officer at the Kenya Marine and Fisheries Research Institute before moving to Thailand on a mangrove rehabiliation project. She is currently involved in an IUCN project on the environmental management of the River Rufiji Delta in Tanzania. Her address: Department of Botany, University of Dar-Es-Salaam, P.O. Box 35060, Dar-Es-Salaam, Tanzania. E-mail: aheronl@yahoo.com

Nico Koedam was trained as a biologist and started physio-ecological research on temperate forest plants. Besides an ecology, biogeography and nature management teaching assignment, he is now heading the research unit General Botany and Nature Management of the Vrije Universiteit Brussel, which has major ongoing vegetation research programs (remote sensing and field analysis) on Kenyan, Sri Lankan and Indian mangrove ecosystems (Indian Ocean); a smaller research program was initiated in Mauritanian mangroves (Atlantic Ocean). His address: Laboratory of General Botany and Nature Management, Mangrove Management Group, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussel, Belgium. E-mail: nikoedam@vub.ac.be