Impact of Human Physical Disturbance on Mangrove Forest Structure at the Gazi Bay, Kenya

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Abstract

Human physical disturbance is prevalent in mangrove forests of the Western Indian Ocean. This study investigated the impact of human physical disturbance on the structure of mangrove forests by comparing forest attributes such as density, taxon richness, stem diameter and tree height between disturbed and relatively undisturbed sites. Physical disturbance was evaluated through tree harvesting intensity, roads and footpaths and other human activities, such as digging for fish bait at the sites. Disturbed sites recorded significantly (ANOVA, $P<0.001$) higher tree cutting intensity than comparable undisturbed sites, corresponding to lower forest complexity and changes in dominant tree species. Disturbance increased prevalence of *Avicennia marina* and *Ceriops tagal* species at the landward margin of disturbed sites. Disturbed sites also recorded significantly lower abundance of harvestable trees and stand volume (223 stem.ha^{-1}, 14.56 m^3.ha^{-1}, respectively) than undisturbed sites (288 stem.ha^{-1}, 19.69 m^3.ha^{-1}, respectively). In addition, accessible sites recorded lower marketable trees, heights, pole size classes (*mazio* 4-6cm, *boriti* >10cm) and species (*Rhizophora* and *Bruguiera*), being dominated by juvenile and stunted *Ceriops* and *Avicennia*. These results indicate that overexploitation of mangrove forests affects the species composition and structural complexity of the forest and hence may impair forest functioning and regeneration and subsequently, sustainable exploitation. Thus, human physical disturbance leads to exponential decline in forest complexity and requires management intervention.

Key words:Mangrove species, abundance, cutting intensity, harvestable trees, forest complexity

Introduction

Mangrove forests are trees and shrubs, belonging to 20 families and 80 species, that line 137,760 km^2 of tropical and sub-tropical coastlines (Kokwaro, 1985; Bandaranayake, 1998; UNEP, 2011). Tropical coastal communities exploit mangrove forests as a source of goods and services, with an estimated global economic value of 1.6 Billion US$.$year^{-1}$ (Diop, 1993; Kathiresan & Bingham, 2001). Typically, resource poor tropical communities regard the forest as a source of affordable, durable and accessible construction material, fuel-wood, tannins, dyes and medicine (Kokwaro, 1985; Farnsworth & Ellison, 1997; Bandaranayake, 1998; Taylor *et al.*, 2003; Singh *et al.*, 2010). Mangrove forest aerial extent, has been closely correlated to marine fisheries yield (Alongi, 2002), being important nursery and feeding habitat for fish and crustaceans (Krumme, 2003; Crona & Ronnback, 2005), and provides powerful justification for their conservation and protection.

Global mangrove forest cover has however declined by 50% in the last decade attributed to anthropogenic physical, chemical and biological disturbances (Farnsworth and Ellison, 1997; Valiela *et al.,* 2001; FAO, 2007; McGowan *et al.*, 2010, UNEP, 2011). Physical deforestation and overexploitation of mangrove forests, due to harvesting of timber products by local communities is widespread in tropical regions throughout the world, and is probably as old as coastal settlements (Semesi, 1998; Singh *et al.*, 2010).

Overexploitation (change detection studies have shown that) of mangrove forests has been measured using remote sensing techniques in Kenya (Doute *et al.*, 1981; Gang & Agastiva, 1992; Dahdouh-Guebas *et al.*, 2004; Kairo *et al.*, 2002) and elsewhere. A number of studies have shown that mangrove deforestation (removal of mangrove vegetation cover) and overexploitation (extractive use of mangrove forest products or habitats) influences assemblage of mangrove flora (e.g. Gang & Agastiva, 1992; Abhuodha & Kairo, 2001; Dahdouh-Guebas *et al.*, 2004) and fauna (e.g. Schrijvers *et al.,* 1995; Fondo & Martens, 1998; Pereira & Goncalves, 2000; Skilleter & Warren, 2000; Khalil, 2001), in Kenya and elsewhere. These studies have reported decline in floral and faunal diversity, as a result of human physical disturbance, but few have described the structure of the disturbed forests in any detail. Such basic knowledge is essential to understanding and explaining the impacts of deforestation on forest functioning as described in some of the above studies and hence the present study. The aim of the

current study was therefore to compare forest structure in a disturbed and relatively undisturbed sites in the Gazi forest.

Materials and Methods

Study Area

This study was conducted at Gazi Bay mangrove forest (Fig. 1). Gazi bay (4^0 25' S, 39^0 30' E) is located in Kwale District, approximately 50 Km south of Mombasa city along the Kenyan coastline. Chale peninsula and a fringing coral reef shelter the bay from incoming oceanic waves. The bay occupies an area of about 1,500 ha, consisting of mangrove forest (615 ha), creek (25 ha), intertidal mud and sand flats (300 ha) and 500 ha of subtidal seagrass beds. The forest experiences semidiurnal tides with tidal amplitude of between 1 and 4 m. Freshwater input into the forest and bay is from groundwater seepage and two seasonal rivers; Kidogoweni and Mkurumuji. The Kidogoweni River bisects the forest and divides it into the Village and Swere forest.

Gazi and Makongeni villages border the forest to the West and Northwest, respectively and have populations estimated at between 3,000 to 5,000 persons (UNEP, 2011). Small scale subsistence agriculture and plantations of cashew nuts, coconuts, mangoes and citrus fruits, occurs on land adjacent to the forest. However, the main economic activity of communities adjacent to the forest is artisanal fishing using baited line, unmotorized canoes and dhows.

Two sites on either shores of the Kidogoweni River were used during the data collection. The Village undisturbed site (E 039° 30.595' S 04° 24.780') was situated to the west of Kidogoweni Creek; about 5km from Gazi village (Fig. 1). The site was accessible from Gazi village through a foot path (~2m wide), while another footpath (1-2m wide) passed through the forest. This site corresponds to the *Ceriops tagal* plot used by Slim *et al.* (1996). The *Village disturbed* site (E 039° 30.670' S 04° 25.148') was closest to the Gazi village being less than 1km from the village to the west of Kidogoweni Creek. The site was the most accessible to villagers having four footpaths and two roads passing through the forest (Fig. 1). This site corresponds to the disturbed site as used by Fondo & Martens (1998), Huxham *et al.* (2004) and Bosire *et al.* (2004) and was chosen to represent a disturbed site at the village forest. The *Swere undisturbed* site (E 039° 30.911 S 04° 25.173') was situated to the East of Kidogoweni Creek (Fig. 1). The site was accessed by crossing through the village forest (~2km) and a canoe or boat ride (~30 min) across the creek. This site corresponds to the virgin habitat described by Slim *et al.* (1996) and Huxham *et al.* (2004). The *Swere disturbed* site (E 039° 30.911 S 04° 25.173') was situated to the East of Kidogoweni Creek (Fig. 1).
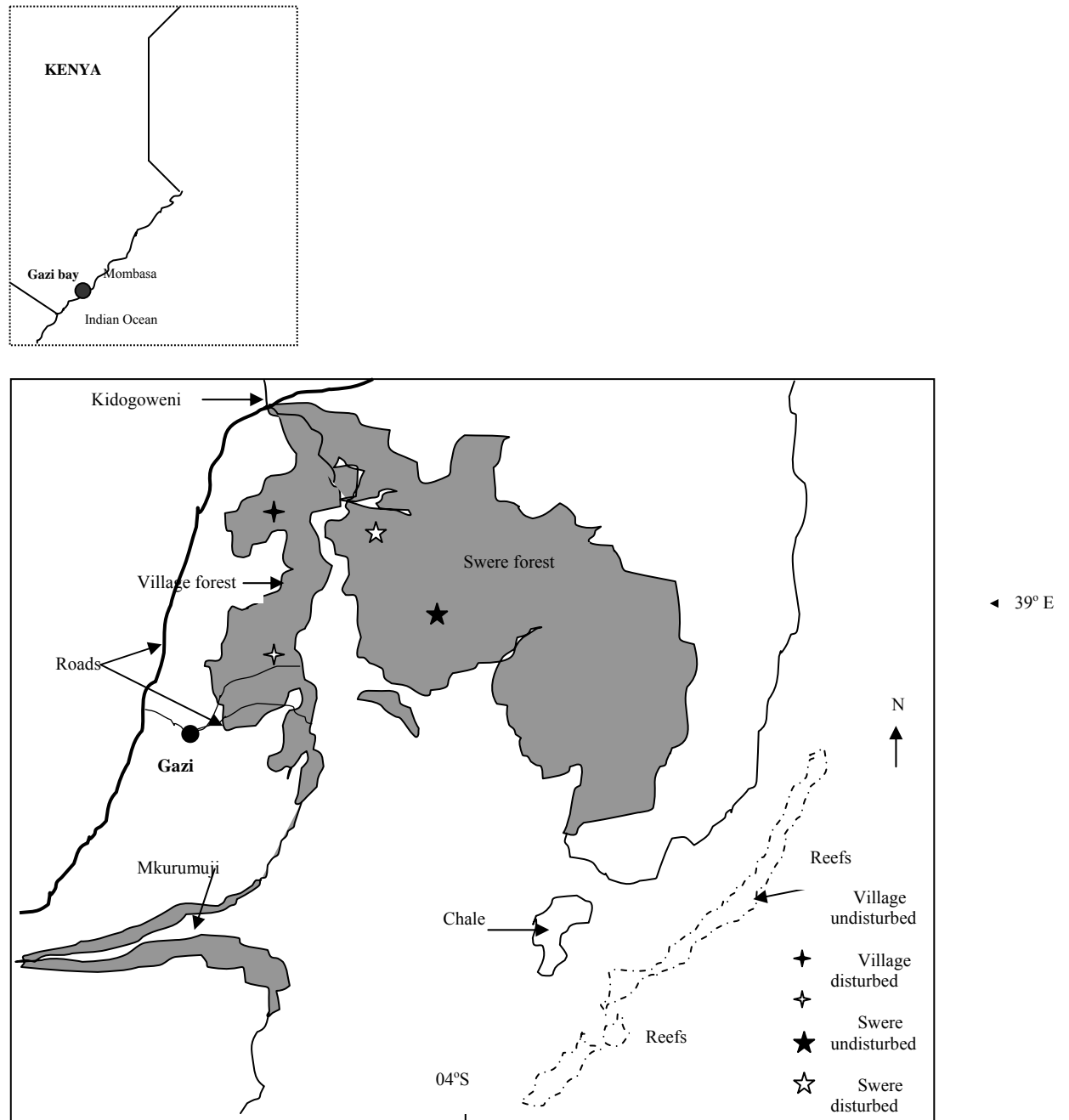
Figure 1. *Location of Gazi bay along the Kenya coast and a detailed map of the Gazi Bay mangrove forest, showing the location of the disturbed and undisturbed sites of Village and Swere, respectively, used in the current study (the mangrove forest is represented by the shaded area)*

The site was accessed by crossing through the village forest (~2km) and a canoe or boat ride (~30 min) across the creek. This site was chosen to represent a disturbed site on Swere forest.

Completely randomized block design was used in the current study with each treatment represented by level of disturbance (disturbed and undisturbed) and each block represented by the sites (Village and Swere). Replication and sampling points were allocated randomly at the respective sampling stations.

Data Collection and Analyses

Four line transects of variable lengths (200-2000m), depending on forest extent , were laid from the landward to seaward margin at each of the four sites (Village undisturbed and disturbed and Swere undisturbed and disturbed). Data on human disturbance and forest structure were recorded on 5X5m plots at intervals of 10 m along the line transects. Human disturbance was evaluated by recording the density of cut trees, presence of roads and footpaths and also presence and abundance of holes dug to collect fish bait. Forest structural attributes were determined by evaluation of species abundance, height, diameter at breast height and also abundance of harvestable trees (i.e. trees with long straight branches and above 2 cm diameter). The data was used to calculate importance value and structural complexity index (CI) using the following formulae;

$$IV = RA + RD + Rdom \tag{1}$$

Where IV- importance value, RA- Relative abundance, RD- Relative density, Relative dominance.

$$CI = TR * d * a * ht \tag{2}$$

Where CI- Complexity index, TR- Taxon Richness, d- Stem density, a- Basal area, ht- Tree height.

Measurements of stem diameter were also used to elucidate size composition at each site and species and the following size categories were set; >2 cm-Juveniles, 2-4 cm- *Fito*, 4-10 cm - *Boriti*, 10< cm- *Mazio*. The above size classes are related to use classes of mangrove products among local communities (Dahdouh-Guebas *et al*, 2000; Abuodha & Kairo, 2001).

The data collected was tested for homogeneity of variance prior to ANOVA. Significant differences were separated using Tukeys' Honestly Significant Difference (Tukey's HSD) test (SPSS, 1992).

Results

Mangrove tree cutting, trampling by man and vehicles and digging for fish bait by fishermen were the main forms of human physical disturbance observed at the Gazi forest (Table 1). Tree cutting intensity was significantly higher at disturbed sites, especially on the village forest sites (498 cut.ha^{-1}), compared to the relatively undisturbed sites (One way ANOVA: F=4.7, df =3, n=342, P<0.01). In addition, footpaths, motorable roads and bait holes were more commonly encountered at sites closer to and accessible to local communities, such as the disturbed site of Village forest.

Table 1: Variations in human disturbance parameters at disturbed and undisturbed sites within Gazi forest, Kenya

Human activity	Village undisturbed	Village disturbed	Swere undisturbed	Swere disturbed
Tree cutting (cuts.ha^{-1})	$325\pm78_{ab}$	$498\pm106_b$	$69\pm64_a$	$231\pm87_{ab}$
Roads (no.)	0	2	0	0
Footpaths (no.)	2	4	0	1
Bait holes (no.)	2	10	0	1

Means in row with the same letter a, or b attached are not significantly different (Tukey HSD, α=0.05)

Six mangrove species were encountered along transect laid from land to the seaward margin at the four sampling sites, of which *Ceriops tagal* (C.B. Robinson), *Rhizophora mucronata* (Lam.), *Avicennia marina* (Vierh.) and *Bruguiera gymnorrhiza* (Lam.) were common to all the sites (Table 2). *C. tagal* was the most important species at the undisturbed site of Village forest, while *A. marina,* dominated in terms of occurrence, abundance and contribution to biomass (DBH) at the corresponding disturbed sites of the Village forest (Table 2). *Sonneratia alba* and *Xylocarpus granatum* were only encountered at the Village forest sites. At the Village forest, *A. marina* increased in importance at disturbed sites from 15.4% at undisturbed Village site to 122.3 % at the corresponding disturbed site, whereas other species declined in importance (Table 2).

At the Swere forest, *R. mucronata, C. tagal* and *B. gymnorrhiza* were dominant in terms of abundance and contribution to biomass (Table 2). The importance value of *C. tagal* doubled from 39.2 % at the undisturbed site of the Swere forest to 89.3 % at the corresponding disturbed site.

Table 2: Occurrence and distribution of mangrove species encountered at sites in the Gazi Bay, Kenya

Sites	Species	Basal area (m²/ha)	Relative dominance (%)	Relative density (%)	Relative Frequency (%)	Importance value (%)
Village undisturbed	*C. tagal*	12.75	9.29	72.87	41.50	123.67
	R. mucronata	9.48	0.95	10.05	26.07	37.08
	A. marina	2.21	0.10	4.68	10.64	15.43
	B. gymonorhiza	1.06	0.04	3.39	9.47	12.86
	X. granatum	0.80	0.07	9.00	11.86	20.92
	S. alba	0	0	0	0	0
Village disturbed	*C. tagal*	5.22	1.52	29.21	18.75	49.49
	R. mucronata	1.99	0.28	14.07	6.35	20.60
	A. marina	12.70	6.74	53.05	62.25	122.29
	B. gymonorhiza	2.87	0.06	2.09	6.25	8.4
	X. granatum	0.31	0	1.09	3.13	4.22
	S. alba	0.27	0	0.50	3.13	3.63
Swere undisturbed	*C. tagal*	7.56	1.27	16.80	21.14	39.21
	R. mucronata	31.15	19.55	62.72	41.59	123.86
	A. marina	6.71	0.13	1.89	9.82	11.84
	B. gymonorhiza	16.83	0.03	18.59	27.18	48.90
	X. granatum	0	0	0	0	0
	S. alba	0	0	0	0	0
Swere disturbed	*C. tagal*	7.19	4.28	59.54	25.49	89.33
	R. mucronata	25.74	9.39	36.49	42.17	88.05
	A. marina	1.39	0.01	0.64	6.25	6.90
	B. gymonorhiza	16.13	0.54	3.33	25.50	29.36
	X. granatum	0	0	0	0	0
	S. alba	0	0	0	0	0

Importance value (IV) = ∑relative frequency, dominance and density per species; *Basal area*= $\pi dbh^2/4$

The undisturbed site of Swere forest recorded significantly higher standing stem density, harvestable trees density, tree height and stem diameter (One way ANOVA log Abundance F=5.28, df=3, P<0.05; Harvestable trees; F=4.90, df=3, P<0.01: log Tree height; F=10.98, df=3, P<0.001: Log DBH; F=8.29, df=3, P<0.001). On the other hand, the lowest stem density 575 stem.ha⁻¹ recorded at the disturbed village forest site corresponded to the lowest harvestable tree density (104 stem.ha⁻¹) and basal area 2.78m².ha⁻¹ (Table 3). The stand volume at both sites in the village forest (7 to 9 m³.ha⁻¹) was less than half of those reported at the Swere forest 19 to 31m³.ha⁻¹.

Table 3: Some forest stand characteristic at undisturbed and disturbed sites within Gazi Bay mangrove forest, Kenya (Values displayed are pooled means (±SE) for the sites)

Forest character	Village undisturbed	Village disturbed	Swere undisturbed	Swere disturbed
Stem density (stem.ha^{-1})	2464 ±134	575 ±183	5040±110	4082±150
Harvestable trees (stem.ha^{-1})	253±76$_{ab}$	104±10.5$_c$	524±63$_a$	342±85$_{ab}$
Tree Diameter (cm)	18.90±3.74$_a$	18.85±5.12$_a$	28.21±3.10$_a$	24.33±4.18$_a$
Basal area (m^2.ha^{-1})	2.80±1.10	2.78±2.06	6.24±0.76	4.65±1.37
Tree Height (m)	2.84±1.07$_d$	3.52±1.12$_c$	5.02±1.06$_a$	4.16±1.07$_b$
Stand volume (m^3.ha^{-1})	7.95±1.18	9.79±2.31	31.32±0.81	19.34±1.46

Row means (±SE) with the same letter a, b or c attached are not significantly different (Tukey HSD, α=0.05): *Stand volume*= Basal area*tree height.

Significant difference in the size class composition were recorded among the sites (Kruskal Wallis χ^2=9.5, df=3, P<0.05). At all the sites juveniles were more abundant than adults by a factor of between 1 and 12 times. The lowest ratio of juveniles to adults was recorded at the disturbed site of Village forest (4:3), while the highest (25:2) at the undisturbed site of Village forest. *C. tagal* juveniles were the most abundant at all sites, apart from the disturbed site of Village forest, where *A. marina* juveniles predominated (Figure 2). T test comparison showed that, *C. tagal* and *Rhizophora mucronata* juveniles were more abundant at undisturbed sites than comparable disturbed (*Ceriops*; t=40.6, Gund-Gdis; t=2.2, Swere: *Rhizophora*; t=25.4, 8.7, P<0.05). Human disturbance thus, influenced mangrove forest regeneration through impact on juvenile density.
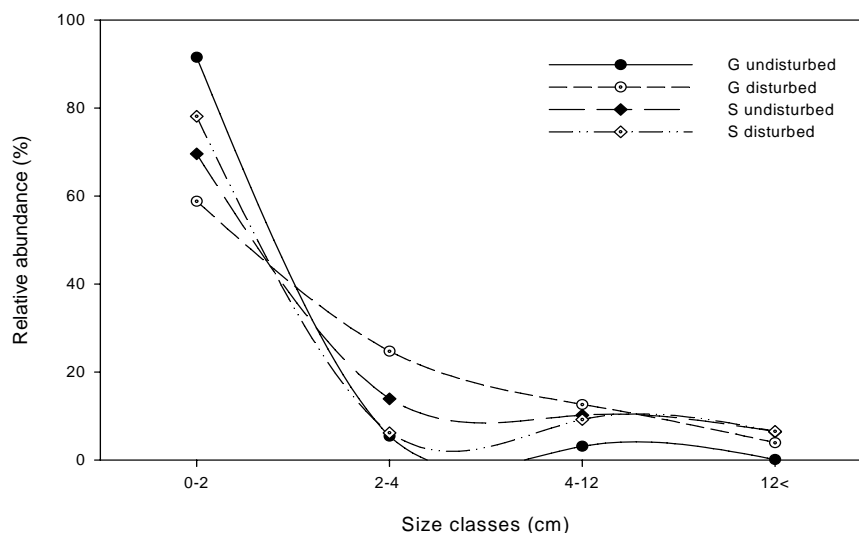

Figure 2: Occurrence of mangrove stem size classes among the sampling sites within the Gazi forest

Juveniles sized poles were always more abundant at disturbed sites compared to corresponding undisturbed sites at the Village and Swere forest sites, but the difference in representation of juveniles was only significant at the Village forest site (Village: t=12.3, P<0.05; Swere: t= 1.99, P>0.05). Similarly, differences in representation of adult size classes were observed at the sites, in that, at the Village forest sites all adult size classes (2-4, 4-12 and 12<) were more abundant at the disturbed site, than corresponding undisturbed site (Figure 3). While at the Swere sites, the *fito* (2-4 cm) class were more abundant at the undisturbed site than at the disturbed site, and all other adult classes had similar representation (Figure 3).

Juveniles and *fito* size classes of *Ceriops*, *Avicennia* and *Rhizophora* were most abundant at both disturbed and undisturbed sites of the village forest with stem densities of above 800 stems.ha^{-1} being recorded (Figure 3). *Mazio* pole size classes of *Ceriops* and *Rhizophora* were commonly abundant at all sites, but at the village sites *Avicennia mazio* were also abundant, with densities of above 190 poles.ha^{-1}.*Boriti* poles at the Village forest were dominated by *Avicennia* poles, especially at the disturbed site where densities of above 50 poles.ha^{-1} were recorded. At the Swere forest, there was a greater variety of boriti poles dominated by *Rhizophora* where lower pole densities were encountered at the undisturbed site.

At the undisturbed site of Swere forest, *mazio* and *boriti* poles of the four common species *C. tagal*, *R. mucronata*, *A. marina* and *B. gymnorhiza* were more common than all other sites. *Ceriops* and *Rhizophora* species dominated both juvenile and other size classes at the site. At the disturbed site of Swere forest regeneration of *Ceriops*, *Rhizophora* and *Bruguiera* was more prevalent than comparable undisturbed sites. *Xylocarpus* and *Sonneratia* were absent from the Swere sites, while *Avicennia* were only encountered as larger poles of *Mazio* and *Boriti* sizes. Therefore, human exploitation, alters the species composition of the forest from *Rhizophora* dominated to *Avicennia* domination.
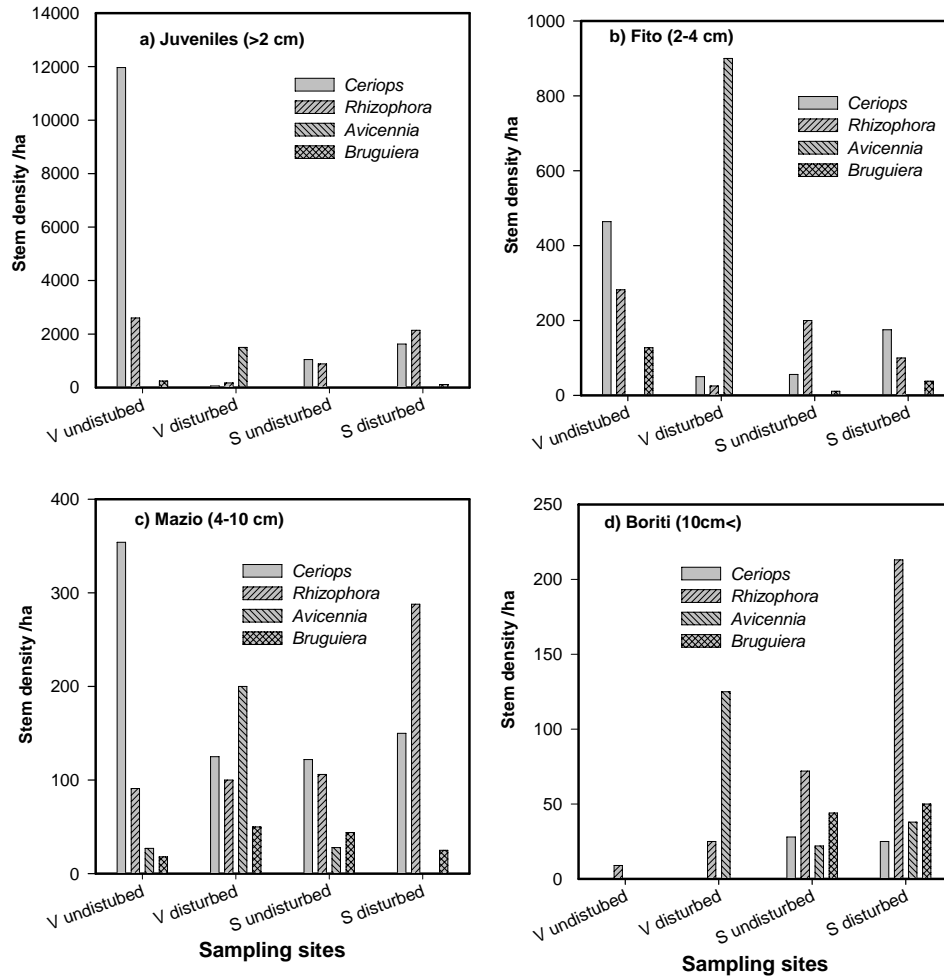
Figure 3: Occurrence of stem size classes on mangrove species at the disturbed and undisturbed sites of the Village (V) and Swere (S) sites at the Gazi mangrove forest, Kenya

Mangrove tree height and abundance of harvestable trees remaining at the sampling sites was dependent on the level of human disturbance (ANOVA: Harvestable trees; F=4.9, df=3. P<0.01; Tree height, F= 5.8, df=3, P<0.001). Increase in levels of human disturbance corresponded to lower abundance of harvestable trees, tree diameter and height (Table 3). Harvestable tree abundance and tree height were significantly higher at the Swere forest compared to sites at the Village forest (Tukey HSD, α=0.05). In addition, the disturbed site of Village forest had the lowest harvestable tree density and tree height (Tukey HSD, α=0.05). The diameter of mangrove trees within the sites were however similar and ranged between 18 mm at the disturbed site of village forest and 28 mm at the undisturbed site of Swere forest (ANOVA;

DBH, F=1.6, df=3 P>0.05). Hence, human disturbance and exploitation reduces harvestable tree density and overall height of the forest.

Although the village forest site had higher taxon richness (5 & 6 for undisturbed and disturbed respectively), they recorded lower complexity (97.80 & 33.74 for undisturbed and disturbed respectively) than both Swere forest sites (506 & 315 for undisturbed and disturbed respectively) (Fig 4). This was attributed to the lower stem densities, tree height and basal area which were below 3.0 compared to Swere forest with values above 4 for each category (see Table 3).

The highest forest complexity (506.1) was recorded at undisturbed site in the Swere forest and this was nearly twenty times higher than (33.7) that recorded at the disturbed site of the village forest (Figure 4). Human disturbance result in an exponential decline in forest complexity.
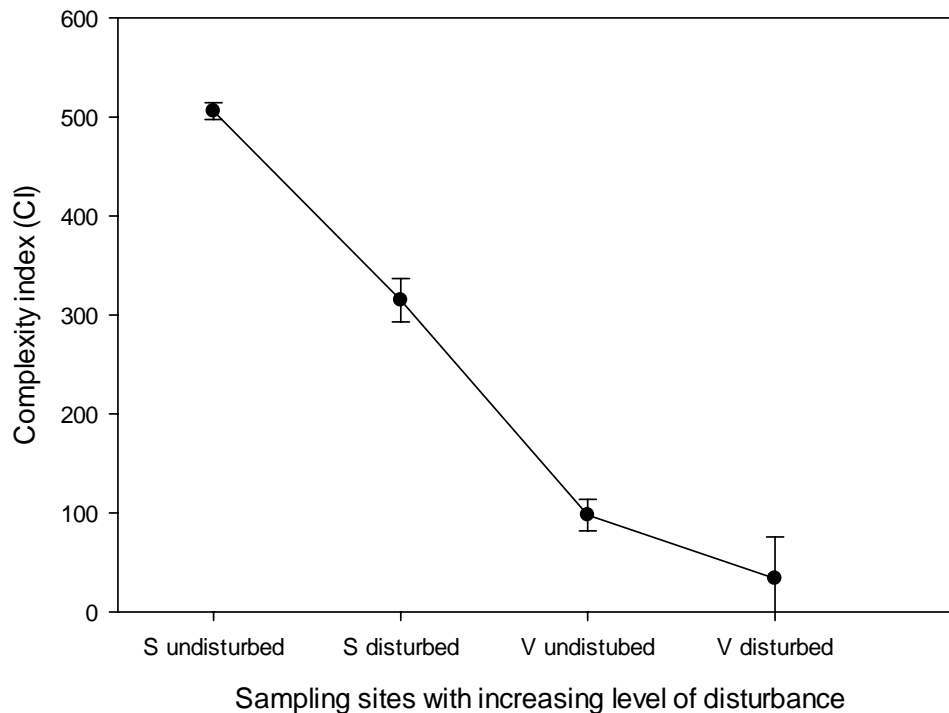

Figure 4: Variations in forest complexity (CI) with disturbance at the Gazi forest, Kenya (Values are means ±SE)

Discussions

The most common form of human physical disturbance that occurred at the Gazi mangrove forest was the cutting of mangrove trees to meet the local and commercial demand for forest products. Trampling and subsequent compaction of the forest floor was done by both vehicles and man. Trampling occurs when community members and other visitors to the forest, traverse the forest to access the fisheries grounds, the mainstay of adjacent community's economy, and also for tourism and research purposes. It was also observed that the mangrove forest floor was an important source of fish bait for the local fishermen. The baits were caught by digging holes in the muddy substrate and may have targeted the large polychaetes . There are also reports that the mangrove gastropod *Terebralia palustris* is collected for human consumption in times of crop failure (Dr. J. Kairo, Pers. Comm.). These findings have implications for tropical mangrove forest management and conservation in Kenya and elsewhere, since mangrove forests, which fringe 75% of tropical coastlines, not only provide forest products, but also fishing bait and access to traditional fishing grounds and tourist features. This is the first study that has reported beach access and also bait excavation, as an additional importance of mangrove, and hence these should be further evaluated for inclusion in current mangrove ecosystem service evaluation.

On average, the harvesting of mangrove trees at Gazi forest occurred at a rate of 2.8 trees.m^{-2} equivalent to the removal of 2,800 trees.ha^{-1}, giving a total of 505,350 trees extracted from the whole forest. The average density of stems with diameter above 2 cm was estimated at 30.4 trees.m^{-2} (304,000 trees.ha^{-1}), implying that tree harvesting at Gazi forest removed 9% of existing harvestable trees. Kairo *et al.* (2002) reported higher tree standing stocks of over 560,000 trees.ha^{-1} (< 5cm stem diameter) in mangrove forests within protected areas in Lamu, Kenya. In the same study they calculated a potential yield of 1,736 trees.ha^{-1} for the forest, which represented 0.3% of standing stock. Noting that the harvesting at Gazi forest targeted juvenile trees with diameter below 5 cm and that the rate of extraction (9%) reported in this study was much higher than that recommended for a protected area in Kenya, it is clear that the Gazi mangrove forest is heavily overexploited.

Assuming that each tree harvested was sold in the local market for about 1.3 $US (~100 Kshs), the total value of mangrove forest products harvested from Gazi mangrove forest is estimated at over 0.63 Million $ US (Ksh. 50 million). However, this estimate represents all the tree stumps still existing within the forest at the time of the study and gives no idea about the yearly, monthly or daily rate of extraction. The estimate however suffices as a first

estimate of the rate of mangrove forest exploitation in a Kenyan mangrove forest.

The rate of human disturbance was governed by accessibility of the site to local communities. Hence, forests closer to and more accessible to local communities by either vehicles, foot or boats, such as the disturbed sites of Village and Swere forest experienced higher tree extraction than comparable but inaccessible sites . Similar results were obtained by De Boer *et al.* (2002) who showed that patterns of mangrove invertebrate faunal exploitation were also dependent on the accessibility of sites to man.

The disturbance at Gazi forest has led to a 40 to 50% decline in predominant tree height and harvestable trees from the disturbed compared to undisturbed sites. Stunting and low forest cover is commonly associated with overexploited forests, and has been reported in Pacific Island of Kosrae (Allen *et al.*, (2001), and in Kenya by Kairo *et al.* (2002) and Dahdouh-Guebas *et al.* (2000) in mangrove forests of the Kenyan North coast. The observed degradation ultimately influences forest functioning, through decline in productivity (Kihia *et al*., 2010) and herbivory (Kihia *et al*., 2011).

Human disturbance has also reduced the prevalence of commercially valuable species such as *Rhizophora* and *Bruguiera* and their replacement by less valuable species, such as *Avicennia* and *Ceriops,* at disturbed sites. Overexploitation of mangrove forests leads to creation of large gaps within the forest; regeneration within the gaps created, is then influenced by prevailing physico-chemical profiles of the substrate and the regenerative ability of the colonizing tree species (Allen *et al.*, 2001; Duke, 2001). *Avicennia* species is euryhaline, occurring at both the upper and lower intertidal zone of Gazi forest (Dahdouh-Guebas *et al.*, 2004) and combines both reproductive and vegetative growth strategies to dominate highly disturbed sites, as compared to *Rhizophora* species (Duke, 2001). Dahdouh-Guebas *et al.* (2004) also reported that historically, Gazi forest was more extensive than the present forest and was dominated by *Rhizophora* species, but overexploitation of preferred species (*Rhizophora*) had led to 51% decline of the forest.

Stunting of the mangrove forest at the disturbed sites of Gazi forest, could also be due to size selectivity among the mangrove harvesters. Preferred size classes, such as *boriti* and *mazio*, which are of greater market value are overexploited at the Gazi forest. Walters (2003) showed that size selectivity of mangrove harvesters, altered the size frequency distribution of mangrove forests, from the normal sigmoid (j shape) curve at undisturbed sites to a

bimodal one with a prevalence of young and old mangrove trees, similar to the forest structure at disturbed sites described in the current study.

Exponential decline in forest complexity as a result of human physical disturbance has been demonstrated in the current study, and provides further evidence of the detrimental impacts of man on mangrove ecosystem (e.g. Farnsworth & Ellison, 1997). While the underlying causes, such as substrate quality deterioration, coupled with excessive extraction, may influence susceptibility of surviving biota. This is further complicated by the physical chemical complexity of this tidally influenced habitat, which ultimately determines survival and recovery of forest attributes.

Conclusions and Recommendations

Human disturbance in the form of overexploitation for forest and non-forest products occurs at the Gazi forest. The exploitation of mangrove forests significantly reduces abundance of trees with preferred stems sizes and species, leaving the forest dominated by juvenile, stunted and old *Avicennia* trees. Regenerative ability of mangrove species within gaps created during harvesting, however, may obscure patterns of diversity and abundance change, due to natural recolonization of the habitats created. Simplification of mangrove forest's structural and biological complexity may ultimately influence both nutrient and biomass processing capacity of the forest. Managing levels of human disturbance is hence, crucial to the survival of these fragile habitats, to allow recovery of pristine ecosystem attributes.

Acknowledgements

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