PROGRESS REPORT

ASSESSMENT

OF

MANGROVE FOREST STRUCTURE & BIODIVERSITY OF GAZI BAY

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A progress report submitted to Rufford Small Grants Foundation as part of the funding support for the project *"Promoting sustainable ecotourism for conservation and management of mangroves in Gazi Bay –Kenya"*

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1. Introduction

Mangroves are known to offer various ecosystem goods and services. Their wood products have been exploited for building, firewood and other uses. They also serve as breeding grounds for fish, buffer the shoreline against storms and wave energy, captures and stores carbon dioxide among other ecosystem services. However, mangroves globally face threats from human activities and climate change impacts, which negatively impacts on the ecological integrity of mangrove ecosystems. Various efforts including the active involvement of communities living adjacent to the mangroves have been put in place worldwide to enhance the management and conservation of mangrove forests. In Gazi Bay, the mangroves are managed jointly between Kenya forest Services (KFS) and Community Forest Association (GOGACOFA) which is made up of 12 community forest user groups.

Gazi Women Boardwalk group is one of the user groups, which was established in 2006 to promote the conservation and protection of mangroves using ecotourism. Also, the group is involved in creating awareness on the value of mangroves to locals (villagers and schools), visiting students from other parts of the country and international tourists. The project is designed to generate revenue through the visit upon which the income is channeled towards community development projects and restoration of degraded mangrove areas. However, since the launch of the project in 2006, no survey has been done to assess both the impacts of the project to mangrove biodiversity and impacts of illegal human activities on the forest structure adjacent to the ecotourism site. By establishing baseline conditions of the mangrove forest stand adjacent to the project, a review of the community management approaches can be done effectively to optimize conservation benefits.

The Gazi Bay covers a total of 615ha of mangrove-forested land. All the nine mangrove species described in the Kenyan coast are found in this ecosystem i. e *Ceriops tagal*, *Rhizophora mucronata*, *Avecinnia marina*, *Bruguiera gymnorrhiza*, *Sonneratia alba* and *Xylocarpus granatum*, *Xylocarpus moluncensis*, *Heritiera littoralis*, *Lumnitzera racemorsa* with *C. tagal* and *R.mucronata* being the dominant species. Gazi Bay mangroves are not only providing habitats to a range of fauna such as crabs, molluscs but also to primates (monkeys) and has been identified as a home to several marine and migratory birds (GVI Kenya, 2011). The successful implementation of this RSG funded project will result in the provision of additional data that will support conservation and enhancement of biodiversity in the area; regionally as well as on a global scale contributing to protection of endangered key species.

Due to its ecological and biodiversity relevance, Gazi mangrove system has attracted both local and international scientists and students working closely with communities to support sustainable utilization and management of mangroves resources. Following a long history of mangrove research, Gazi Bay hosts a community ecotourism project that aim to minimize local pressure, promote alternative livelihoods and

conservation of mangrove and associated ecosystems. This proposed project aims to promote sustainable conservation and management of mangroves in Gazi bay through marketing of a community led ecotourism initiative.

2. Methodology

2.1 Study Area

Gazi bay is located on the south of Kenya in Kwale County (4° 25' S and 39° 5' E). Chale peninsular from the east and a fringing reef from the south protects the bay from strong waves. It has a total surface area of 18km^2 and 615ha of mangrove-forested land (Doute et al., 1981). Gazi Bay is made up of two major creeks, one in the western side of the mouth of river Kidogoweni and Kinondo creek in the eastern side. The bay has a semi-diurnal tidal regime with amplitude varying between 2.90 m at spring tide and 0.70 m at neap tide (Hemminga et al., 1994). The mangroves are rarely supplied with fresh water because the two rivers discharging into the bay (Kidogoweni in the north and Mkurumuji in the south) are seasonal and temporal depending on the amount of rainfall.

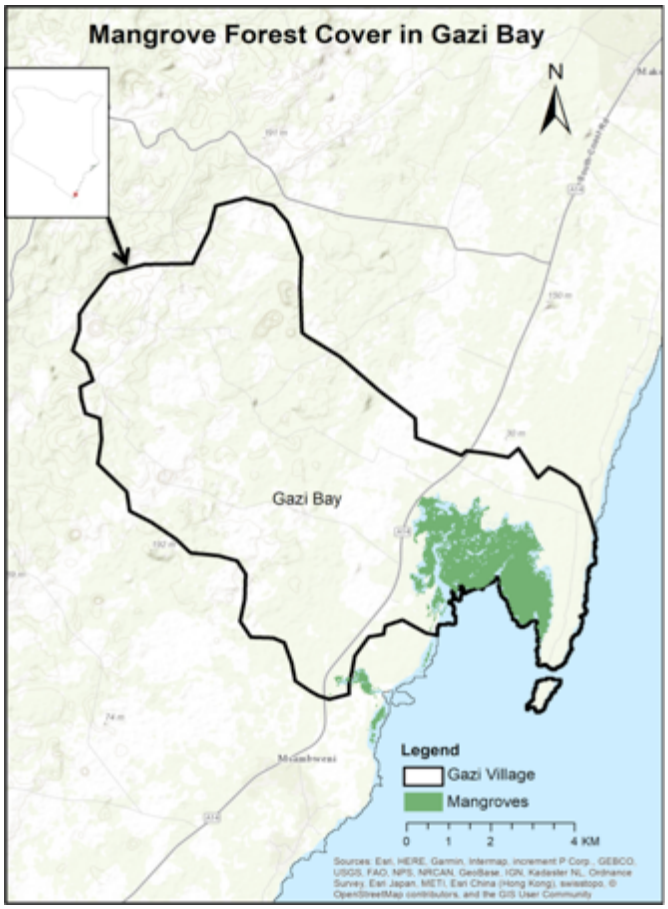

Figure 1: Mangrove forest cover and distribution

All nine species of mangroves documented in Kenya has been found growing in the bay with *C. tagal* and *R. mucronata* being the most dominant species. Mangroves of the bay provide essential ecosystem goods and services to the adjacent coastal communities such as; wood, shoreline protection, carbon sequestration and supports artisanal fisheries. Forest exploitation for fuel and construction demand has greatly undermined the ecosystem integrity (Kairo et al., 2009).

2.2 Sampling design and data collection

2.2.1 Stand Density and pole quality

Five plots of 10m * 10m in the proximity of the Gazi Women Boardwalk were randomly selected, set, marked and sampled to provide baseline information about the stand density and pole quality of mangroves in the area. These plots will form Permanent Sampling Plots (PSPs) for future monitoring of human impacts on mangrove forest structure and biodiversity. Growth parameters including Diameter at Breast Height (DBH) and Tree Height were measured in each standing mangrove tree within the sampling plots using a calipers and graduated pole respectively. Data was analyzed to provide derivatives of stand density, pole quality density and forest structure following guidelines developed by Kairo et al. (2002).

Plate 2: Marking of monitoring Permanent Sampling Plots (PSPs)

Plate 1: DBH measurement

2.2.2 Regeneration

Linear sampling within the 100m^2 PSPs was done to assess juvenile density using outlined protocols of FAO (1994). Mangrove juveniles were identified and classified into three regeneration classes: RCI 1-40cm, RCII 40-150cm and RCIII 150-300 cm, <DBH 2.5cm. Densities per hectare were then extrapolated from the data collected.

Plate 3: Juveniles of *Ceriops tagal*

2.2.3 Macro-Fauna assessment

Two 100m long parallel transects were established perpendicular to the creek in Gazi Bay. One transect was established in a semi-pristine (designated conservation/project area) continuing stand denoted as undisturbed (UND). A control transect was established in a highly disturbed (D) area based on observed low stem density and high stumps numbers. Five $100m^2$ plots were established in each transects at 10 meters interval. Within the $100m^2$ sampling plots, fauna presence/absence was assessed within a sub-sample of $1m^2$ quadrats deployed randomly inside the $100m^2$ sampling plots. The sub-quadrat was left undisturbed between 15 to 20 minutes. Faunal numbers and types were counted and recorded and identification carried out with the help of a field guide for Western Indian Ocean region developed by Richmond (2011).

3. RESULTS

3.1 Tree density

The study found the standing stem density at 3340 stems ha^{-1}; *Ceriops tagal* was the most dominant species with *Xylocarpus granatum* being the least dominant at 83.83% and 7.19% respectively (Table 1). The mangrove forest stand around the Gazi Women ecotourism project was dominated by young trees of

diameter ≤6 cm that account for 73.65% of the stand density (Figure 1). The survey did not record either prolific seed bearers or trees >20.1 cm diameter. The high population of *C. tagal, which was the dominant species,* lied between 3-8 meters high. Other species also showed a similar trend in canopy height distribution (Table. 1).

Table 1: Density stand table

	Utilization classes (cm)						
Species	**≤6**	**6.1-9**	**9.1-13**	**13.1-20**	**20.1-35**	**35≥**	**Density ha^{-1}**
Am	20	60	20	-	-	-	100
	(20)	(60)	(20)	-	-	-	(2.99)
Ct	2300	460	40	-	-	-	2800
	(82.14)	(16.43)	(1.43)	-	-	-	(83.83)
Rm	20	60	100	20	-	-	200
	(10)	(30)	(50)	(10)	-	-	(5.99)
Xg	120	60	20	40	-	-	240
	(50)	(25)	(8.33)	(16.67)	-	-	(7.19)
Total	2460	640	180	60	-	-	3340
	(73.65)	(19.16)	(5.39)	(1.80)	-	-	

() figures in parenthesis are percentages
A m – *Avicennia marina*
R m – *Rhizophora mucronata*
C t – *Ceriops tagal*
X g – *Xylocarpus granatum*

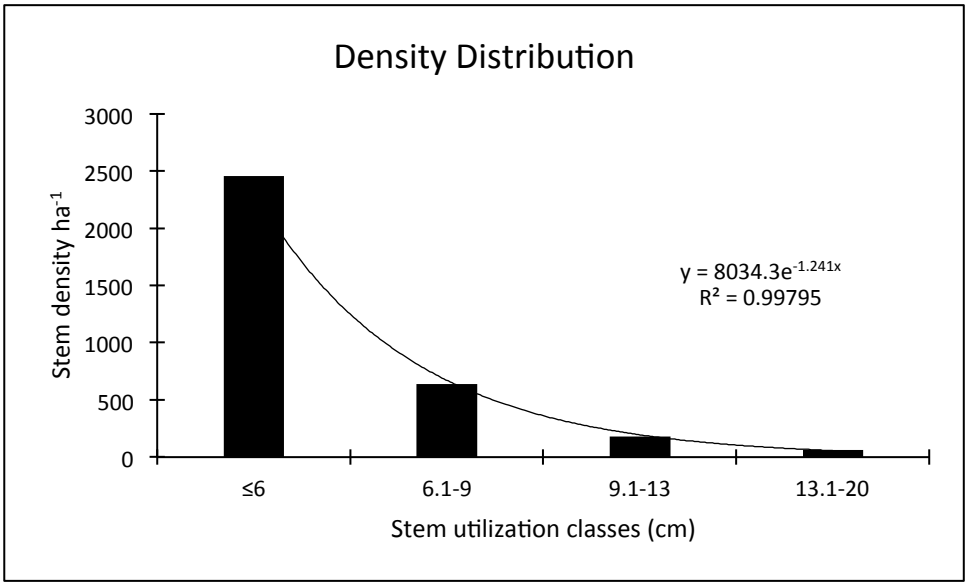

Figure 2: Stand density distribution

3.2 Pole quality

The survey area was found to be dominated by a high density of crooked trees at 56% of the stand categorized as form III (lowest pole quality). Form II and I had 30.54% and 13.17% respectively (Table. 2). On the other hand the diameter-height analysis for *C. tagal* was indicated a weak relationship with a R2 value of 0.1382 (Figure. 3).

Table 2: Pole quality table

		Form (Pole quality)			
		I	**II**	**III**	**Total**
Density		440	1020	1880	3340
	%	(13.17)	(30.54)	(56.29)	

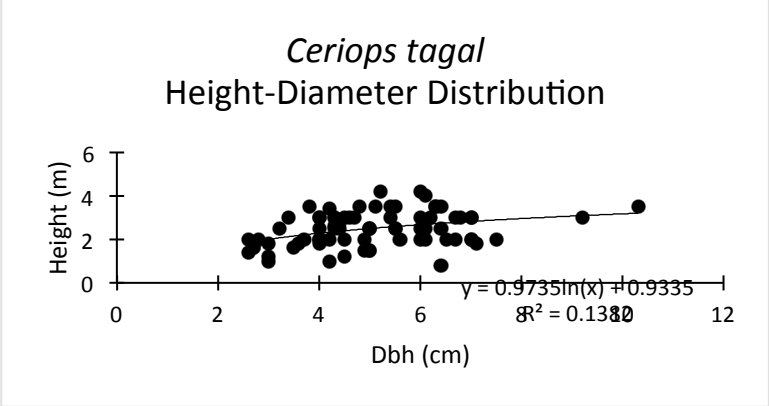

Figure 3: Diameter-Height distribution of *C. tagal*

Four juvenile species were encountered in the project site: *Avicennia marina, Rhizophora mucronata, Ceriops tagal* and *Xylocarpus granatum*. Sapling density of 133,020 saplings ha^{-1} was established, with *C. tagal* and *R. mucronata* accounting for 95% and 4% respectively of the total juvenile density. RCI were approximately 62.97%, while RCIII saplings accounted for less than 1% of the density (Table. 3).

Table 3: Regeneration density distribution

	Regeneration Classes Density ha^{-1}				
Species	**RCI**	**RCII**	**RCIII**	**Total**	**%**
Am	60	0	0	60	(0.05)
Rm	3400	2560	320	6280	(4.72)
Ct	80300	45500	720	126520	(95.11)
Xg	0	160	0	160	(0.12)
Total	83760	48220	1040	133020	
	(62.97)	(36.25)	(0.78)		

() figures in parenthesis are percentages
A m – *Avicennia marina*
R m – *Rhizophora mucronata*

C t – *Ceriops tagal*
X g – *Xylocarpus granatum*

3.3 Fauna assessment

An analysis of faunal assemblages in the project area showed a dominance of crabs in both disturbed and semi-pristine forest areas (Figure 4). Relatively, high faunal densities of 145 crabs m^{-2} and 109 gastropods m^{-2} were observed in semi-pristine zones as compared to the disturbed mangrove forest areas (Table 4). Oysters, *Turbellaria spp*, *Littorina spp* and barnacles were encountered within the study area. Barnacles and oysters were mainly observed attached and occurred in the seaward fridge of the mangrove area indicating inundation class 1.

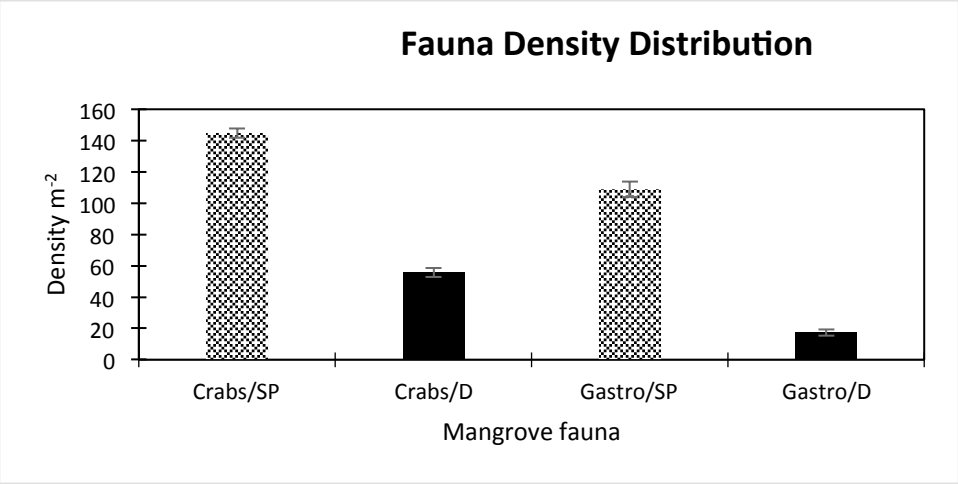

Figure 4: Distribution of macro-fauna in the project areas; gastro=gastropods, SP=Semi-Pristine and D=Disturbed

Table 4: Fauna densities distribution

Fauna Group		**Crabs (**Sesarmids, Uca**)**		**Gastropods**	
Status		Semi-pristine	Disturbed	Semi-Pristine	Disturbed
Plot No.	1	96	140	-	-
	2	136	50	284	21
	3	96	35	48	38
	4	300	34	116	23
	5	96	20	96	5
Density (Fauna m^{-2})		145±3	56±3	109±5	17±2
Figures after (±) are standard errors (s.e)					

4. Discussion

4.1 Floristic productivity

The mangrove area adjacent to the ecotourism project displayed characteristics of a forest recovering from previous disturbance. Approximately, 74% of the stand was composed of young trees under the

utilization class ≤6 cm (Figure 1). Disturbed forests usually exhibit high stand density (>50%) of either young (0-19m) or crooked trees or both, growing as single trunks and thickets. The site's proximity to human settlements exposes the adjacent mangroves to frequent anthropogenic disturbances, and as a result high inferior quality poles density was observed (Mohamed et al., 2009). Progressive decrease in stand density as the diameter utility class increases was indicative of selective harvesting influenced mainly by high local pole demand for mangrove wood products as construction materials.

Nine mangrove species are present in Gazi Bay, however only four species were observed in the sampled plots. These species did not display a systematic mangrove zonation, with *C. tagal* being the dominant species occupying a seaward ecological zone that normally would either be colonized by *A. marina, R.mucronata* or *Sonneratia alba.* Dominance of one species suggested either unsuitability of substrate, few seed bearers or selective species overexploitation (Kairo et al., 2002). The large *C. tagal* population observed was mainly due to the nature of the species acting as a strong colonizer coupled with relatively light propagules that are easily dispersed and deployed (Kairo et al., 2001).

Juvenile density distribution of RCI, RCII and RCIII in ratios of 80.54:46.37:1 was inconsistent to the FAO (1994) proposed ideal density ratio distribution of 5:3:1 indicative of a perpetual forest system. Change in substrate combined with presence of few mature seed bearers could influence distribution and density of juveniles in site. Poor substrate was characterized by dwarfism in *C. tagal* and *A. marina* forest stands (Kairo et al., 2002). Under poor substrate and low propagules production, low density and spatial distribution of juveniles was expected. As an effect of high mortalities between developmental stages triggered by unfavorable ecological growth conditions, uneven distribution of juveniles across the area was observed (Kairo et al., 2001).

4.2 Fauna colonization

The dominance of various mangrove crabs' species suggested that mangroves in the semi-pristine zone were in a recovery phase (Bosire et al., 2004). Similarly, one group's higher density and dominance in areas classified as degraded indicated poor ecosystem functionality (Bosire et al., 2004). Faunal density, distribution and diversity are usually influenced by geo-physical and biological factors *in-situ* and adjacent to the ecosystem. In this context, hardened and open surfaces as an effect of excessive pole

Plate 4: Cerithidia spp

Plate 5: Turbellaria palustris

harvesting could have led to the observed variation in fauna population and types. In totality, this study supports the evidence that mangrove fauna thrive under a canopy complemented by loosely compacted organic substrate. The relatively higher crab and gastropod population indicated that the semi-pristine ecosystem was gravitating towards recovery and mimicking the natural ecosystem. This could be attributed to the restricted and infrequent access to the managed ecotourism project area. Disparities in fauna populations of semi-pristine and degraded site were perhaps as an effect of the community interventions via the ecotourism project on the forest. However, fauna population may not be used conclusively as parameter to assess forest health as it also affected by bio-complex interactions between mangrove associate ecosystems (Dahdouh-Guebas, 2002). This study provides baseline data for the assessment of mangrove forest structure and biodiversity in an area currently co-managed by the community ecotourism group. Information about faunal diversity and forest structure will help to provide a snapshot of the recovery and success of community intervention as an alternative and sustainable approach to mangrove conservation and management.

Plate 6: Fiddler crab

Plate 7: Mangrove spider

5. Conclusions

- *C. tagal* was the dominant species in the area sampled
- The forest displayed dwarfism tendencies.
- Relatively low stand density and species diversity was established.
- High mortality of juveniles was observed.
- The forest is recovering from a previous disturbance.
- Selective harvesting was applied on the forest system.
- There are few prolific seed bearers to sustain production of sufficient juveniles
- Crabs dominated both degraded and semi-pristine stands.

6. Recommendation

- Artificial restocking with desirable species is likely going to restore the degraded areas.
- Regular monitoring and surveillance around the project area to be done in order to prevent illegal harvesting of mangroves.
- A better working relationship to be established between the community and the Kenya Forest Service to enhance management of mangroves in Gazi Bay.
- Development of socio-ecological impact indicators to be used to assess performance of community-led conservation projects.

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