Biodiversity Status of Arabuko Sokoke Forest, Kenya

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BIODIVERSITY STATUS
OF ARABUKO SOKOKE FOREST, KENYA

Edited by:
Ochieng' D., Luvanda A., Wekesa C., Mbuvi M.T.E and Ndalilo L.

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BIODIVERSITY STATUS
OF ARABUKO SOKOKE FOREST, KENYA

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FOREWORD

Arabuko Sokoke Forest (ASF) covers 41,600ha and is the largest single block of coastal forests remaining in East Africa. It is a biodiversity rich forest which harbours unique endemic flora and fauna including rare and endangered plants, mammals and birds. The forest is also of immense importance to the forest adjacent community whose livelihood is substantially dependent on its resources. The forest is facing threats from both anthropogenic and natural factors including climate change which in turn negatively impacts on the biodiversity.

Although ASF is considered one of the most important biodiversity hotspots in Kenya, little information exists about the changing status of its flora and fauna due to impacts of climate change. Although several studies on biodiversity assessment of the forest have been conducted, the data remains either unpublished or presented in an unsystematic manner. In situations where empirical data have been published, majority of studies have only looked at a single vegetation type.

Kenya Forestry Research Institute (KEFRI) through the financial support of Kenya Coastal Development Project (KCDP), and in collaboration with Kenya Wildlife Service (KWS), Kenya Forest Service (KFS) and National Museums of Kenya (NMK) undertook a study to generate baseline information on floral and faunal biodiversity status for proposed continuous monitoring of Arabuko Sokoke Forest. The data generated through continous monitoring will aid in decision making for sustainable conservation and management of the forest in the face of climate change.

This publication presents comprehensive empirical data on the flora and fauna of Arabuko Sokoke Forest. The data presented here will form a benchmark for future biodiversity assessments in the face of climate change. The information will be useful to natural resource managers, policy makers, researchers, students, non-governmental organizations and community based organizations involved in biodiversity conservation to identify strategies for enhancing sustainable conservation and management of Arabuko Sokoke Forest.

I urge that this endeavour is extended to all natural forests in Kenya.

Ben Chikamai (PhD)
Director, Kenya Forestry Research Institute

EXECUTIVE SUMMARY

Biodiversity monitoring is essential for effective conservation and sustainable management of forests. In recent years, there has been an increasing effort to establish temporary and permanent sample plots explicitly for purposes of biodiversity assessments in forests. In light of this, a study was conducted in Arabuko Sokoke Forest (ASF) to collect baseline data as a benchmark for long term monitoring of changes in flora and fauna due to degradation and climate change. The forest was demarcated into three distinct vegetation types namely; Mixed forest, Brachystegia forest and Cynometra forest, and 27 Permanent Sample Plots (PSPs) established across the vegetation types. Several biodiversity indicators were assessed namely: vegetation (woody plants), edaphic factors, mammals (small and large), birds, and herpertofauna. Impact of socio-economic characteristics and governance on ASF was also evaluated.

Tree species richness was slightly high for Brachystegia and Mixed forest but showed slight decline in Cynometra forest and did not change between 2004 and 2015 meaning the floral diversity of the forest has remained relatively intact. High tree species diversity was observed. The soil nutrient levels were significantly different across the different vegetation types.

Brachystegia forest had higher mammal species diversity, but less forest specialists than the Cynometra forest. The occupancy and relative abundance of golden-rumped sengi significantly increased in the Cynometra forest. The Sokoke bushy-tailed mongoose had higher occupancy and abundance within the Brachystegia forest. Blue duiker (*Philantomba monticola*) and golden-rumped sengi occupancy was positively correlated with distance to the forest boundary. Buffaloes and elephants presence was evident in some vegetation zones especially the Mixed forest. Small mammals were mostly restricted to the Cynometra forest type.

Birds showed distinctive distributions among the three habitat types, with the Brachystegia woodland emerging as the most preferred. The Cynometra zone had significantly lower abundance followed by Mixed forest. Overall, 36 birds species within 17 families were recorded. Five feeding guilds were registered across the sites. The Brachystegia woodland had the highest (all the five) among the survey sites, while the Cynometra forest had the least feeding guilds represented.

Twenty three individuals of herpes were recorded comprising of 9 species. Reptiles were represented by 3 families and amphibians by 2 families. Lizards' species followed by snakes were the most diverse and abundant. Speke's Sand Lizard *(Heliobolus spekii*) was only found in Brachystegia woodland. Herpertofauna diversity was least in Cynometra forest type.

The quantity of forest products extracted had declined over the years. This decline was mainly attributed to low demand for forest products especially poles and posts resulting from poor performance of the local economy. Besides, forest governance and management has deteriorated from the period before colonization era to date. The deterioration was attributed to unlawful means of accessing resources, poverty, and lack of incentives for communities to meaningfully participate in forest management. Proposed mitigation measures were: to ensure sensitization and awareness of stakeholders; and provision of incentives to enable communities effectively participate in forest management.

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LIST OF ACRONYMS

ASFADA	Arabuko Sokoke Forest Adjacent Dwellers Association
ASF	Arabuko Sokoke Forest
ASAR	Arid and Semi Arid Region
ANOVA	Analysis of Variance
ArcGIS	Aeronautical Reconnaisance Coverage Geographic Information System
BD	Bulk Density
BFP	Brachystegia Forest Point
CFP	Cynometra Forest Point
CBO	Community Based Organisation
CEC	Cation Exchange Capacity
CVC	Credit Valley Conservation
C/N	Carbon Nitrogen Ratio
CFAs	Community Forest Associations
DBH	Diameter at Breast Height
EU	European Union
EC	Electrical Conductivity
ESRI	Environmental System Research Institute
FD	Forest Department
FAO	Food and Agricuture Organisation of the United Nations
FAC	Forest Adjacent Community
GBC	Global Biodiversity Conservation
GEF	Global Environment Fund
GENSTAT	General Statistical Software Packge
GCC	Global Climate Change
IBA	Important Bird Area
IGA	Income Generating Activities
IUCN	International Union for Conservation of Nature
KEFMP	Kenya Forest Master Plan
KCDP	Kenya Coastal Development Project
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
KFS	Kenya Forest Service
KIFCON	Kenya Indigenous Forest Conservation Program

KBA	Key Biodiversity Area
KFMP	Kenya Forest Management Programme
LSD	Least Significant Difference
Ms Excel	Microsoft Excel
MFP	Mixed Forest Point
NMK	National Museum of Kenya
NGO	Non-Governmental Organizations
NMDS	Non-Metric Multidimensional Scaling
NCCRS	National Climate Change Response Strategy
NTFP	Non Timber Forest Products
pH	Potential Hydrogen
PPM	Parts per Million
PSP	Permanent Sample Plot
PIE	Picture Image Extraction
REGWQ	Ryan Einof Gabriel Welsch multiple range Test
RAI	Relative Abundance Index
SOM	Soil Organic Matter
SAS	Statistical Analysis System
SID	Society for International Development
STDEV	Standard Deviation and Variance
TLS	Time Limited Searches
UNEP	United Nations Environment Programme
UTM	Universal Transverse Mercator
UOC	Utilizable Organic Carbon
ZSL	Zoology Society of London

CHAPTER 1: BACKGROUND INFORMATION

C. Wekesa, J. Otuoma, P. Ongugo, G. Muturi and D. Ochieng

1.0 Introduction

One of the objectives of Kenya's national climate change response strategy is to develop mitigation and adaptation measures against loss of biodiversity in forest and woodland ecosystems (NCCRS, 2010). However, lack of long-term empirical data on status of biodiversity in these ecosystems has emerged as a major limitation in most African countries including Kenya. This limitation stems from uncertainties associated with declining environmental quality and loss of biodiversity to either anthropogenic causes such as deforestation and forest degradation, and climate change. Although the anthropogenic factors are linked to global climate change, the two operate at different spatial-temporal scales and may require different intervention strategies. Effective intervention strategies against climate change require a long-term monitoring mechanism on response of flora, fauna, and related environmental variables across several sites with a view of generating adequate empirical data for decision making.

Arabuko Sokoke Forest (ASF) is ranked second in Africa and fifty globally in biodiversity richness. It is the largest remnant of what was originally an extensive strip of dry coastal forest that extended from Southern Somalia in the horn of Africa to the Eastern Cape in the south (Forest Department, 2002; Oyugi *et al.*, 2007). Although previously considered to be a northern relic of the Miombo Woodland Forest of Southern Africa, recent studies have indicated that the forest's vegetation community changes progressively and manifests in high floristic and faunal endemism as it stretches North from the Southern Miombo Woodlands of Mozambique and Zambia (Moll and White, 1978; Oyugi *et al.*, 2007). Thus, unlike the Miombo, which is dominated by Brachystegia forest, ASF is made up of three forest types, namely: an undifferentiated Mixed forest; Cynometra forest; and Brachystegia forest (Forest Department, 2002).

Despite being subjected to decades of deforestation and degradation, the forest remains a global biodiversity repository. It is estimated to hold about; 50 species of globally rare plant species, three internationally endangered mammal species, six globally threatened bird species, many species of reptiles and invertebrates, and four endemic butterfly species (Collar and Stuart, 1998; Forest Department, 2002; Lange, 2003; Oyugi *et al.*, 2007). Its international significance in biodiversity conservation makes ASF a principal candidate for long-term studies on impacts of climate change on biodiversity.

Kenya Forestry Research Institute (KEFRI), National Museums of Kenya (NMK), Kenya Forest Service (KFS), and Kenya Wildlife Service (KWS) undertook a study to establish the diversity of flora, fauna, and edaphic factors as well as the impact of local communities on the forest conditions in Arabuko Sokoke Forest (ASF). The objective of the study was to establish baseline information for long-term monitoring to inform policy and decision making on biodiversity dynamics in ASF.

1.1 Physiography of Arabuko Sokoke Forest

Arabuko Sokoke Forest is the largest single block of remnant indigenous coastal forest in Eastern Africa. It covers a total area of about 41,600ha. The forest is situated along Kenya's coast strip traversing Kilifi County at latitude 3° 20' S and longitude 39° 50' E (Figure 1.1). The eastern boundary of the forest lies on a flat coastal plain at an elevation of 45m above sea level (a.s.l.). This rises to a plateau at 60 - 200 m a.s.l. in the central and western parts of the forest (Figure 1.2).

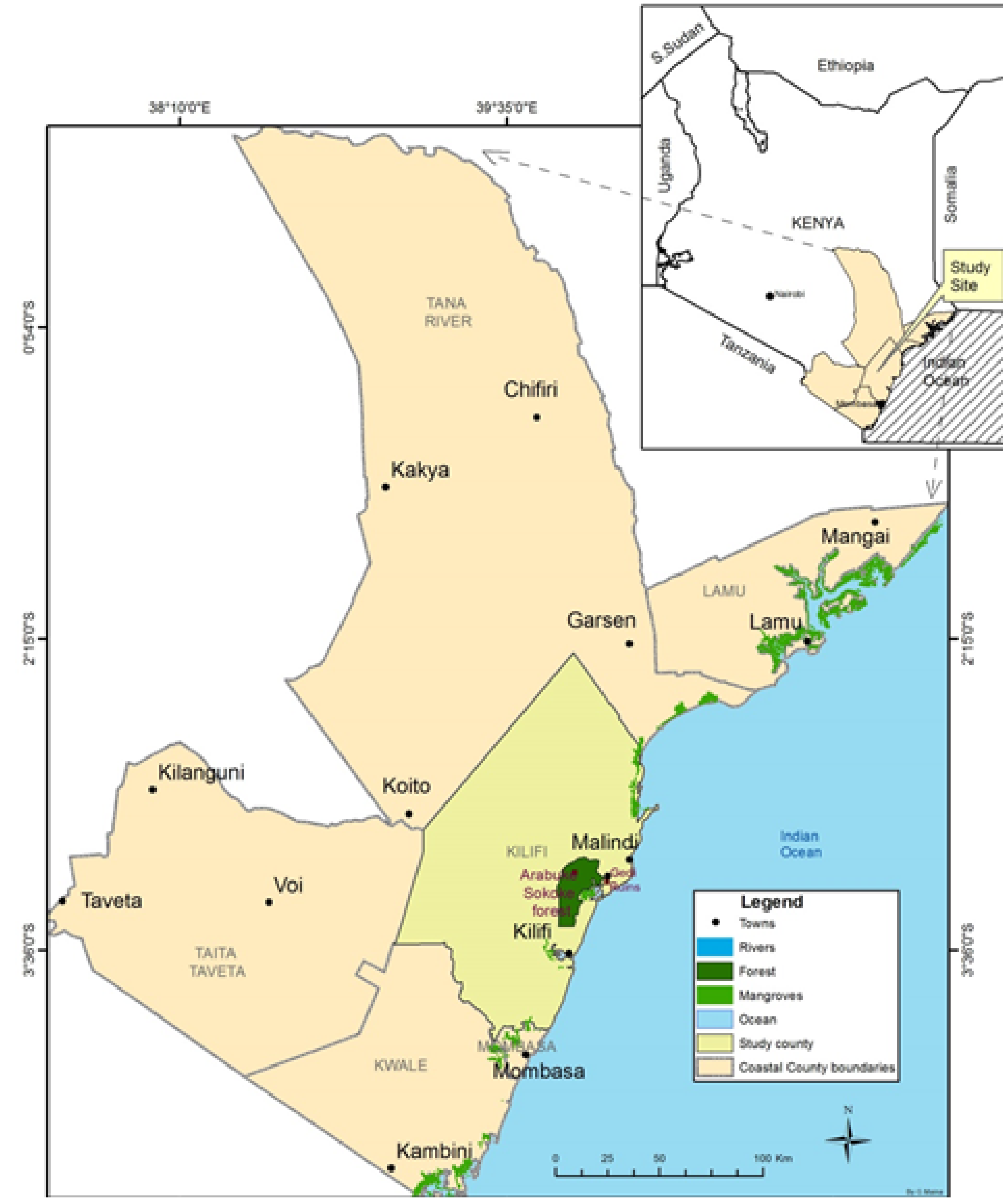

Figure 1.1: *Location of Kilifi County and the Arabuko Sokoke Forest within Coast region of Kenya*

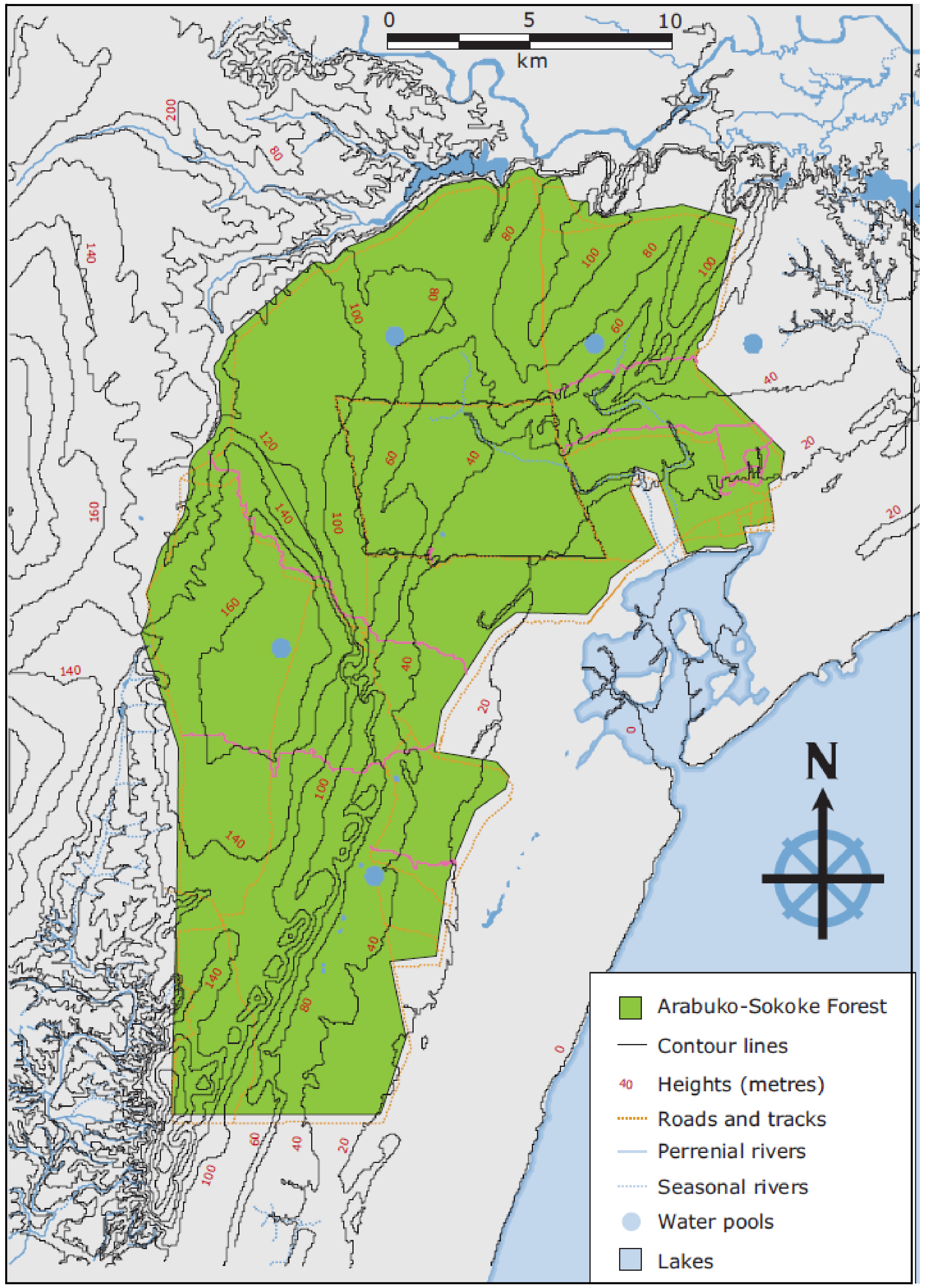

Figure 1.2: *Topographic map of Arabuko Sokoke Forest*
Source: ASFMT, 2002

1.2 Biodiversity conservation status

Arabuko Sokoke Forest was declared as Crown forest in 1932 and thereafter gazetted as a forest reserve in 1943. An additional 2,675ha of Kararacha area in the South East was added to the gazetted forest in 1968. In 1977, an area of 4,300ha was designated as a Nature Reserve and set apart exclusively for biodiversity conservation. The nature reserve had expanded to 5,935ha by 1979. Currently, the forest covers a total area of about 41,600ha.

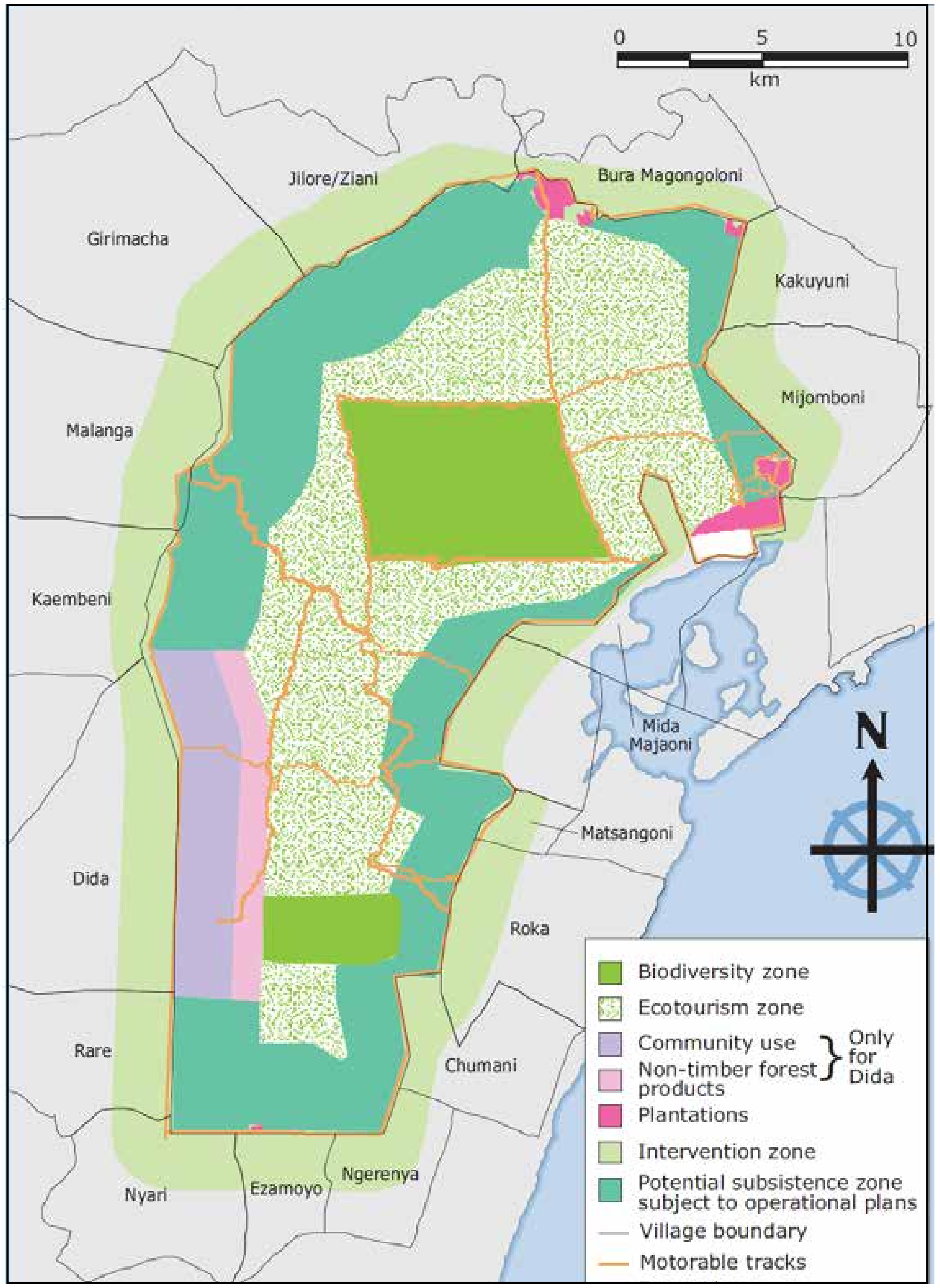

Figure 1.3: Arabuko Sokoke Forest Management zones
Source: ASFMT, 2002

The forest is a rich reservoir of biodiversity, including a high concentration of endemic and endangered flora and fauna. Over 600 plant species have been recorded in the forest, 50 of which are globally rare (Oyugi *et al.*, 2007). Fifty-two mammal species have been recorded in this forest, including three taxa which are globally threatened: the Golden-rumped Elephant-shrew (of which 90% of the known global population lives in ASF); the Sokoke Bushy-tailed Mongoose (one of the 5 mongoose species recorded); and Ader's Duiker (which has only one other population in Zanzibar). The forest is also a refuge for some of Kenya's less common mammal species and supports a herd of about 70 elephants. It is currently ranked as the second most important forest for conservation of threatened bird species in mainland Africa. Over 230 bird species have been recorded in the forest, including six globally threatened bird species: Clarke's Weaver (endemic to the forest and its immediate surroundings), Sokoke Scops Owl, Amani Sunbird and Sokoke Pipit (all of which are near-endemics), Spotted Ground Thrush (a rare migrant); and East Coast Akalat (a rare species confined to East African coastal forests). Diverse populations of reptiles and invertebrates are also present in the forest. The latter include more than 250 recorded species of butterfly, four of which are endemic.

1.3 Vegetation types in Arabuko Sokoke Forest

Arabuko-Sokoke Forest is made up of three major vegetation types namely; Mixed forest, Brachystegia forest, and Cynometra forest. Mixed forest comprises dense, undifferentiated vegetation, which covers an area of about 7,000ha on the wetter coastal sands in the East of Arabuko-Sokoke Forest. The Mixed forest is highly diverse in tree flora and comprises; *Afzelia quanzensis, Hymenaea verrucosa, Combretum schumannii, Manilkara sansibarensis* and *Encephalartos hildebrandtii.* Brachystegia forest is open vegetation forest on the drier and infertile white sands in the center of the forest and covers 7,700ha. The Brachystegia forest is dominated by *Brachystegia spiciformis*. Cynometra forest is a dense forest thicket on the north-west side of Arabuko-Sokoke and covers about 23,500ha on the red Magarini sands towards the Western side of the forest. Cynometra forest is dominated by *Cynometra webberi, Manilkara sulcata, Euphorbia candelabrum* and *Brachylaena huillensis.* (ASFMT, 2002).

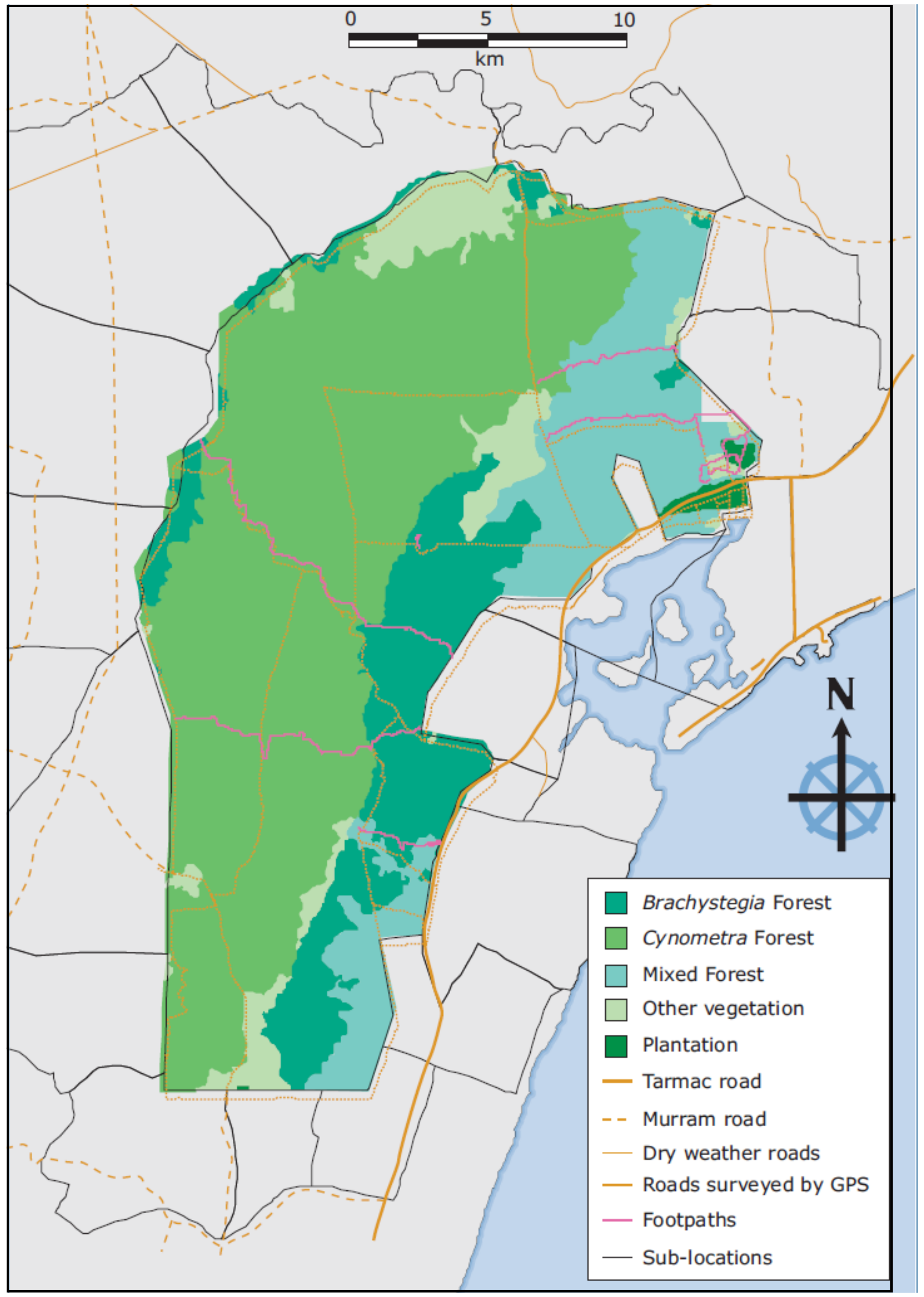

Figure 1.4: Different vegetation types within Arabuko Sokoke Forest
Source: ASFMT, 2002

1.4 Human settlement around the forest

There are approximately 50 villages surrounding ASF with a human population of about 104,000 people (ASFMT, 2002). The main ethnic group in the area is the Giriama. Prior to arrival of the Giriama, the forest was occupied by the Waatha community, who were originally hunters and gatherers and the forest derives its name from them. However, currently there are no squatters residing within the forest. Non-resident cultivation was abandoned due to frequent damage of crops by wild animals that reside within the forest, such as elephants and baboons. Most of the forest-adjacent communities comprise small scale farmers who depend on forest resources to supplement their agricultural produce. The main subsistence crops cultivated by inhabitants include; maize, cassava, and cow peas. Cash crops include; coconut, mango and cashew-nut.

1.5 Rationale

Biodiversity monitoring is essential for effective conservation and sustainable management of natural forests. However, as a benchmark for long-term monitoring, baseline information is of essence. This publication presents results of a study conducted to provide an in depth analysis of the present biodiversity status of ASF ecosystem. This publication provides baseline information on various aspects of the forest including: floristic composition and structure; Edaphic properties of different vegetation zones within ASF: Small and large mammals; Birds; Amphibians and reptiles; and Utilization and governance of ASF.

This publication will:

- form a benchmark for long-term monitoring of flora, fauna, and environmental variables
- provide a basis for future analysis of trends in biodiversity status of ASF
- form basis for long term empirical studies on impact of climate change on biodiversity
- provide a basis for designing forest management strategies
- provide a basis for mitigation and adaptation to climate change for purposes of biodiversity conservation

It is anticipated that ASF will act as a pilot site for similar studies to be extended to other biodiversity hotspots in humid, sub-humid and dryland forest ecosystems within the country.

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CHAPTER 2: FLORISTIC COMPOSITION AND STRUCTURE OF ARABUKO SOKOKE FOREST

C. Wekesa, J. Otuoma, J. Ngugi and G. Muturi

2.0 Introduction

Arabuko Sokoke Forest (ASF) is a northern relic of the Miombo woodland forest of Southern Africa. Studies have indicated that the vegetation community changes progressively and manifests high floristic endemism from the Southern Miombo woodlands of Mozambique and Zambia (Moll and White, 1978; Oyugi *et al*., 2007). For instance, the Miombo is dominated by Brachystegia forest, while Arabuko Sokoke Forest comprises undifferentiated Mixed forest and Cynometra forest alongside Brachystegia forest (Forest Department, 2002). Although ASF has been subjected to disturbance for close to a century, it remains a globally recognized biodiversity repository. Over 600 plant species have been recorded in the forest. Estimates indicate that it is home to about 50 species of globally rare plant species (Oyugi *et al*., 2007). The forest is presently ranked second in international significance for biodiversity conservation in Africa (Collar and Stuart, 1998; Bennun and Njoroge, 1999; Oyugi *et al*., 2007). Its elevated status as a biodiversity hotspot has, however, not spared it the vagaries associated with human population growth and subsequent increase in demand for forest products, agricultural land, and game trophy (Forest Department, 2002).

As Kenya embarks on long-term initiatives to monitor forest ecosystems as part of its national climate change response agenda, availability of databases on flora and fauna composition, in biodiversity hotspots has been identified as an important step in providing critical information for developing climate change mitigation and adaptation strategies for sustainable conservation of biodiversity. Though previous studies have been undertaken on biodiversity assessment of ASF, the data remains either unpublished or presented in qualitative and descriptive format (Awimbo and Wairungu, 1990; Mutangah and Mwaura, 1992; Robertson and Luke, 1993; Wairungu *et al*., 1993; Muchiri *et al*., 2001). In situations where empirical data have been published, majority of studies have only looked at a single vegetation type (Oyugi *et al*., 2007). It is therefore important to have comprehensive information on the stand structure and floristic composition of the forest as a benchmark for future biodiversity assessments in the face of changing climate.

This chapter presents in-depth analysis of the floristic composition and structural attributes of the three vegetation types of ASF, namely: Mixed forest; Brachystegia forest; and Cynometra forest. The information presented in this chapter provides a benchmark for long-term monitoring of vegetation to ascertain the changes in flora diversity due to impacts of climate change.

2.1 Sampling design and data collection

Although KEFRI had previously established Permanent Sample Plots (PSPs) in 1990 to assess changes in diversity in flora within ASF over time, the size of the plot used (20m by 20m) was too small to allow for collection of adequate data to show how plant species responded to changes in climatic conditions. More data on flora diversity requires to be collected, characterized, and analyzed over a longer period of time to precisely determine impacts of climate change on vegetation diversity. Consequently, this study was carried out in a 50ha research block dedicated exclusively to long-term assessment of flora within ASF and covered all the three forest types.

The forest types were treated as sub-blocks and served as the treatments in the study. Assessment was carried out in 50m by 20m PSPs. Two sub-plots (10m by 5m and 2m by 1m) were nested within the sample plot. It employed a nested experimental design (Kuehl, 2000; Onwuegbuzie and Leech, 2007). The sub-blocks were nested in the 50ha research block, while the 50m by 20m PSPs were nested in the sub-blocks. The sample size was determined using species area curves (Figure 2.1), which was calculated using data that was obtained from an earlier study in 2004 (Wairungu *et al*., 2004).

Stratified-systematic sampling was employed to collect data from the 50m by 20m sample plots. The 50m by 20m sample plot was used to assess woody plants with DBH > 10cm; the 10m by 5m sub-plot was used to assess woody plants within the 2cm - 10cm DBH range; while the 2m by 1m sub-plot was used to assess tree seedlings and herbaceous life-forms. Plant species were identified by their botanical and local names with assistance of a plant taxonomist and two local para-taxonomists. Data on tree DBH were obtained by measuring tree diameter in centimeters at 1.3m above ground level using a diameter tape. The DBH of trees with a buttress was measured above the buttress. Tree height was measured in meters using a Suunto clinometer.

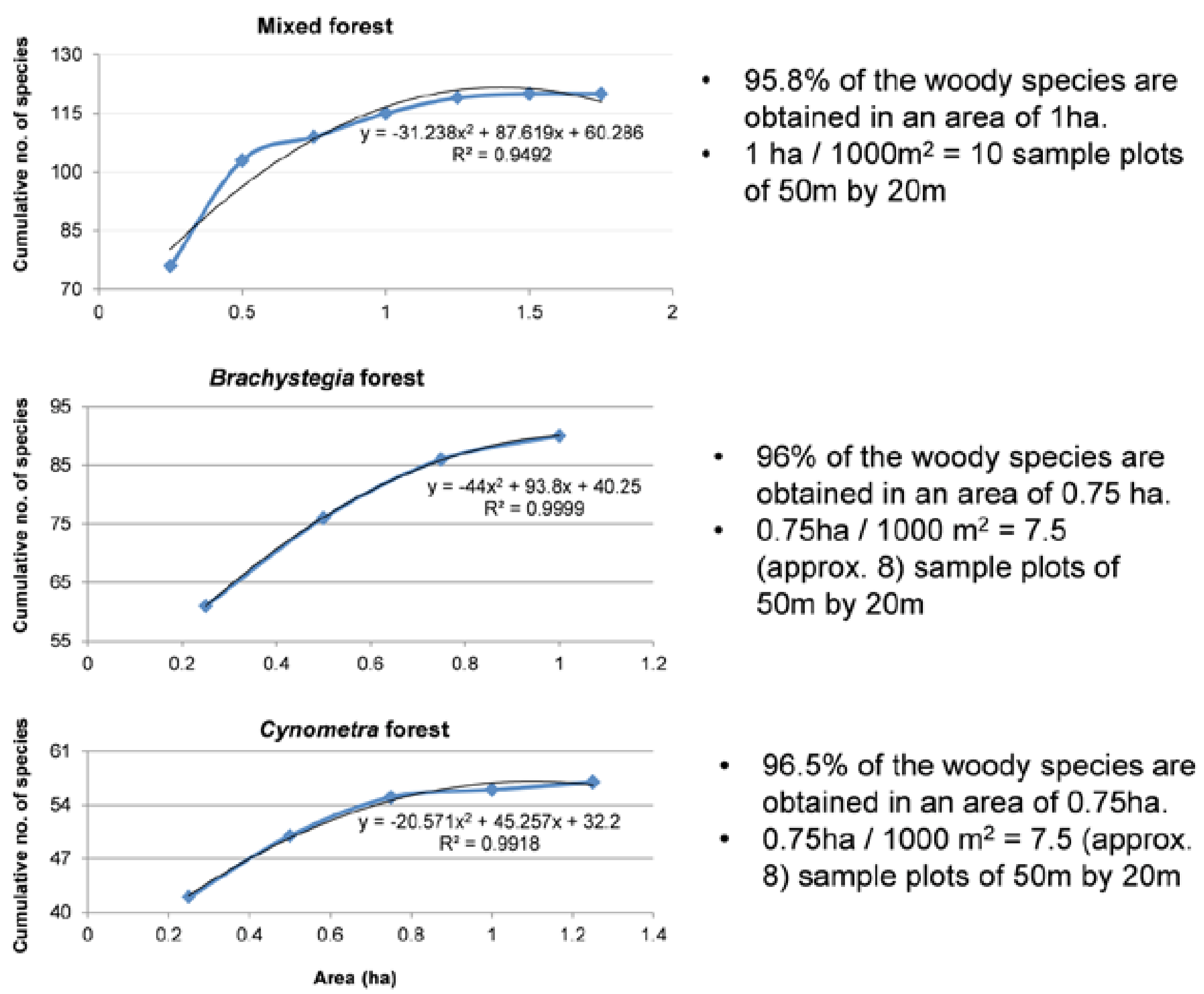

Figure 2.1: Species-area curves showing appropriate sample size for Mixed, Brachystegia and Cynometra forests in Arabuko Sokoke Forest

2.2 Data analysis

Species diversity and evenness were described using Shannon diversity index and Simpson diversity index, respectively (Magurran, 2004; Newton, 2007). Woody species importance value index was calculated as the average of relative frequency, relative density and relative basal area (Guariguata *et al.*, 1997; DeWalt *et al.*, 2003; Lu *et al.*, 2010). Stem density and stand basal area were calculated by converting the data to per hectare basis. Variations in species diversity and evenness, stem density, tree height and stand basal area among the three forest types were analyzed using analysis of variance (ANOVA) in Genstat statistical software at 5% significance level (Buysse *et al.*, 2004; VSN International, 2014). In all situations where statistical significance was recorded, post hoc tests were carried out to detect significant differences among means of different variables using the Ryan-Einot-Gabriel-Welsch Multiple Range Test (REGWQ) at 5% significance level (Krull and Craft, 2009; Sokal and Rohlf, 2012).

2.3 Results and discussion

2.4 Species composition

2.4.1 Species richness, diversity, evenness and importance value index

Vegetation assessment showed that species richness for the entire forest was 179. Mixed forest exhibited the highest species richness followed by Brachystegia forest (Table 2.1). Generally, species richness did not significantly deviate from values obtained from a previous study (Wairungu *et al.*, 2004) but were slightly higher in the current study for Brachystegia and Mixed forest, and declined in Cynometra forest. Saplings and seedlings showed greater species richness compared to trees across the vegetation types (Table 2.1).

Apart from Brachystegia forest where seedlings had higher species richness than saplings, species richness was generally higher for saplings than seedlings in Cynometra and Mixed forests (Table 2.1). The low species richness for both regenerates observed in Cynometra forest could be attributed to high stem density of trees with DBH > 10cm that hindered undergrowth of diverse species and favoured *Cynometra webberi*. *Cynometra webberi* seedlings prefer closed forest to thrive (Kibet, 2011). Soil in Cynometra forest was tending towards being compact (bulk density of 1.4) and only specialized species could successfully regenerate in this forest type. Similarly, Brachystegia forest experienced low species richness for the regenerates simply because of specialization of species. However, in Mixed forest where the specialization of species was less prominent, richness for seedlings, saplings and mature trees was substantially high. Specialization of species in specific habitats was a key factor that could explain species richness in natural forest ecosystems. The fact that species richness did not significantly change between 2004 and 2015 means that floral diversity of the forest was consistently intact.

Table 2.1: Species richness across vegetation types

Vegetation type	Woody species richness		Seedlings	Saplings	Trees
	Earlier studies (Wairungu *et al.*, 2004)	Present study (2015)	-	-	-
Cynometra forest	57	53	28	37	16
Brachystegia forest	90	92	56	53	19
Mixed forest	120	124	64	79	45
Overall		179	110	115	57

Results of Shannon diversity index revealed that there was no significant variation in species diversity between vegetation types (Table 2.2). This suggests that although Mixed forest contained highest species abundance, the species occurrence was represented by few individuals contributing to lower diversity index than expected. Similarly, species evenness as indicated by Simpson diversity index showed insignificant variation between the vegetation types but was generally low across vegetation types, an indication of poorly distributed tree species in ASF (Table 2.2). Species diversity in all the three forest types was high and confirmed importance of ASF as a biodiversity hot spot (Collar and Stuart, 1998; Bennun and Njoroge, 1999; Oyugi *et al.*, 2007).

Table 2.2: Species diversity and evenness across vegetation types

Vegetation type	Shannon index	Simpson index
Brachystegia forest	5.217±1.3446[a]	0.01768±0.004948[a]
Cynometra forest	4.602±0.5909[a]	0.01742±0.001836[a]
Mixed forest	5.765±0.9233[a]	0.02024±0.003749[a]
	F(1,2) = 1.68;	F(1,2) = 0.98;
	p = 0.295;	p = 0.452;
	L.S.D. = 1.759	L.S.D. = 0.006202

2.5 Stand structure

2.5.1 Stand density, diameter at breast height (DBH), basal area and height

Stem density did not significantly vary between the forest types when all woody trees were compared. However, significant difference was observed in stem density for trees having DBH ≥10cm with Brachystegia forest exhibiting significantly low density compared to Cynometra and Mixed forest types where variation in stem density was not observed. Although Cynometra forest had the lowest species richness, it showed a high tree density (Table 2.3). The low density exhibited by Brachystegia forest could be attributed to poor regeneration and recruitment caused by low soil moisture content that was less than 1% below the permanent wilting point.

Table 2.3: Stem density across vegetation types

Vegetation type	All woody stems (plants ha^{-1})	Stems ≥ 10 cm DBH (stems ha^{-1})
Brachystegia forest	38940±3867[a]	222.2±9.09[a]
Cynometra forest	33234±1582[a]	545±105.07[b]
Mixed forest	36956±4481[a]	383.3±12.02z[ab]
	F(1,2) = 1.19; p = 0.393; L.S.D.	F(1,2) = 7.05; p = 0.049; L.S.D. = 238.7
	= 10,417.6	

Additionally, Brachystegia forest in ASF, have deep sandy soils of low fertility (Oyugi *et al.*, 2007) which seemed to hinder establishment of vegetation. Occurrence of highly specialized species in Cynometra forest absolutely contributed to the high density of stems ≥10cm of DBH. Significant variation existed in mean DBH for all woody plants between the forest types with Brachystegia forest having trees with wider girth followed by Mixed forest and then Cynometra forest (Table 2.4). Variation in DBH among the different forest types was expected as the dominant tree species in each of the forest type have unique form and growth characteristics. *Brachystegia spiciformis* which was the dominant vegetation had big trees up to 25 m tall (Chudno, 1984) while *Cynometra webberi* is a small tree that grows to a height of 18 m. Mixed forest having different species with varied growth characteristics and forms had mean DBH between the other two forest types.

Although significant variation existed in mean DBH values for trees with DBH ≥10cm across the treatments with Brachystegia forest having trees with significantly larger diameters, insignificant variation existed in mean DBH between Cynometra forest and Mixed forest. On the contrary, variation was not observed in mean basal area for woody plants and trees with DBH >10 cm. Although big sized trees characterized Brachystegia forest, the mean basal area was low due to the low stem density in this particular forest type (Table 2.4).

Table 2.4: DBH and basal area across vegetation types. The results could not be compared with findings of Wairungu *et al.*, 2004 because of differences in the methodology

Vegetation type	Mean stem DBH (cm) all woody stems	Mean DBH (cm) DBH>10cm	Basal area (m^2ha^{-1}) all woody stems	Basal area (m^2ha^{-1}) DBH>10cm
Brachystegia forest	18.99±0.7352[c]	25.81±1.667[b]	15.45±1.806[a]	14.5±1.564[a]
Cynometra forest	10.79±0.9864[a]	15.7±0.436[a]	16.05±2.98[a]	11.62±2.789[a]
Mixed forest	13.61±0.1099[b]	18.2±0.933[a]	19.67±5.188[a]	16.24±4.761[a]
	$F_{(1,2)}$ = 38.66; p = 0.002; L.S.D. = 2.632	$F_{(1,2)}$ = 19.72; p = 0.008; L.S.D. = 4.657	$F_{(1,2)}$ = 0.41; p = 0.686; L.S.D. = 13.94	$F_{(1,2)}$ = 0.56; p = 0.610; L.S.D. = 12.24

Brachystegia forest had slightly higher mean height followed by Mixed forest and then Cynometra forest (Table 2.5). Vegetation types significantly contributed to the variability in the height. However, difference observed in mean tree height between the vegetation types was not significant.

Table 2.5: Height across vegetation types

Vegetation	Mean tree height (m)
Brachystegia forest	9.456±1.0138[a]
Cynometra forest	6.67±0.7349[a]
Mixed forest	7.875±0.4148[a]
	F(1,2) = 2.55; p = 0.193; L.S.D. = 3.434

2.6 Conclusion

Species richness was slightly higher for Brachystegia and Mixed forest but declined slightly in Cynometra forest. The fact that species richness did not change between 2004 and 2015 means that floral diversity of the forest is still intact. The plant species diversity was high confirming the importance of ASF as a biodiversity hotspot in terms of flora diversity. Structurally, stem density was high though density of trees with large diameters was low indicating incidences of illegal extraction of trees of specific sizes. Insignificant variation existed in tree diameters between Cynometra and Mixed forest. Vegetation types significantly contributed to variability in height of the trees.

2.7 Recommendations

1. Periodic assessment of the PSPs should be undertaken at the same time as the initial establishment to provide systematic and updated information on the forest structure and plant species composition for sustainable management of the forest.
2. There is need for community awareness on the importance of the forest in biodiversity conservation to reduce incidences of illegal logging in the forest.

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CHAPTER 3: EDAPHIC CHARACTERISATION OF ARABUKO SOKOKE FOREST

R. Mwadalu and M. Gathara

Soil physical and chemical properties in natural forests play a key role in maintaining the ecoytsem functioning. The physical properties of forest soils are influenced by the natural vegetation. Soil physical properties usually affect every aspect of soil fertility and productivity. Soil physical properties determine: ease of root penetration, availability of water, and water absorption by plants. Soil physical properties also influence the distribution of tree species, growth, and forest biomass production (Osman, 2013). Chemical properties of forest soils on the other hand; regulate plant growth, influence ecosystem processes such as nutrient cycling and affect the rate of organic matter decomposition, all of which ultimately affect primary productivity and the forest ecosystem health (Credit Valley Conservation, 2010).

Soil and vegetation exhibit an integral relationship. Soil provides moisture, nutrients and anchorage for vegetation to grow effectively on the land, and vegetation provides protective cover to the soil, suppresses soil erosion, and maintains soil nutrients through litter fall and accumulation and subsequently nutrient cycling (Gao *et al.*, 2014). Consequently, soil quality is of significant importance for: the productivity and sustainability of forest systems; conservation of soil and water resources; accumulation of persistent toxic substances and the contribution forested systems make to the global carbon cycle. Typically, forest soils experience a range of pressures, some due to forest degradation and growth of the trees themselves.

There is increasing demand for better accounting of the condition and health of forest ecosystems to determine whether conditions are improving or deteriorating, and the associated impacts on biodiversity conservation. Monitoring of soil health is useful in providing managers and policy makers with information which can be used for long term planning because trends over time can be used to infer to future conditions. Forest soils monitoring allows conservationists to gain insight into spatial and temporal changes of soil physical and chemical properties over time (Credit Valley Conservation, 2010). Spatial and temporal monitoring of soil dynamics is vital in improving ones understanding of the response of forest soil to changes in climate, pollution and forest management practices (EU, 2010) and how the changes impacts on the flora and fauna diversity.

It is for this reason that soil sampling and profiling was undertaken during the establishment of the Permanent Sample Plots (PSPs) in all the stratified zones of Arabuko Sokoke Forest (ASF) to generate baseline information for long term monitoring of the changes in forest soils over time and how these changes are related to biodiversity conservation (Gao *et al.*, 2014).

3.0 Materials and Methods

3.1 Soil Sampling and Analysis

3.1.1. Leaf litter sampling

Leaf litter sampling was done in all the PSPs established in ASF using a ring with known diameter. In each plot, the ring was randomly tossed three times and litter captured inside the ring collected for weight determination. Leaf litter sampling is meant for long term monitoring of dynamics of soil characteristics that are influenced by litter decomposition.

3.1.2 Soil sampling

In each zone, two soil profiles were dug to establish the existing soil horizons (at the beginning and end of each zone). A soil profile pit of 1.0 m x 1.0 m was dug, soil horizons identified in each profile, and data on the soil horizons recorded. Core samples were obtained from each horizon in each profile for bulk density determination. Bulk density is an indicator for soil compaction which affects the rate of natural regeneration. Soil chemical properties are crucial for predicting ability of soil to support plant growth in forest ecosystems. Soil samples were also obtained from all plots within the three vegetation zones (Brachystegia, Cynometra and Mixed forests) for chemical analysis. In each plot, samples were obtained 1.0 m away from corners of the plot and mixed thoroughly to obtain a composite sample. The samples were put in zip-lock bags and stored in a cooler box to prevent further changes of dynamic nutrients.The soil samples were analyzed for the following components using standard analytical procedures (Okalebo *et al.*, 2002):

1. Texture
2. Total Carbon
3. Nitrogen
4. Potassium
5. Phosphorus
6. Calcium
7. Magnesium
8. Soil organic matter
9. Electrical conductivity

3.2 Data analysis

Statistical tests (mean and standard error) were conducted using MS Excel. Analysis of Variance (ANOVA) was conducted at 95% confidence level using SAS (Version 9.0 for Windows). The means were separated using the Least Significant Difference (LSD) test.

3.3. Results and Discussion

3.3.1. Leaf litter

Leaf litter in ASF was significantly different in the three vegetation types ($p<0.0001$). This could be attributed to seasonality of leaf fall by different tree species found in the different vegetation zones. The Brachystegia zone recorded the highest amount of litter. This could be attributed to the deciduous nature of *Brachystegia speciformis* which led to massive litter fall during the sampling period due to the dry season. However, the amount of leaf litter was generally high in the forest resulting into high level of organic matter. Table 3.1 provides a summary of the physical and chemical properties of soil in ASF.

A common feature of the forest floor was the presence of a litter layer composed of dead leaves, twigs and other fragmented organic materials covering the soil. The litter layers play an important role in soil erosion prevention by absorbing impact energy of raindrops and keeping the infiltration rate high. The soil litter layer also limits soil moisture loss due to evaporation and reduces amplitudes of soil temperature by insulating the surface (Rawat *et al.*, 2009).

The plant litter fall and nutrient cycling processes play a major role in regulation of nutrient availability and net primary production in terrestrial ecosystems. Nitrogen released through decomposition of organic matter is critical for plant productivity and regeneration in many forested ecosystems. Low nitrogen (N) availability may be a particularly important constraint in forests where decomposition and mineralization rates are low. Leaf litter fall constitutes the major part of nutrient pool (Rica *et al.*, 2010). Environmental change is likely to alter decomposition rates through soil biotic activity and indirect effects on litter quality with possible impacts on global carbon budget and nutrient cycling.

Table 3.1: Comparison of mean values (±SD) of soil physical and chemical properties of three forest types (Brachystegia, Cynometra and Mixed forests) in Arabuko Sokoke Forest

Soil parameter	Mixed forest	Brachystegia forest	Cynometra forest	*p* value
pH	6.7±0.07	6.2±0.11	5.8±0.15	0.0003
Electrical conductivity (mS/cm)	0.043±0.04	0.029±0.002	0.032±0.004	0.006
Bulk density (g/cm³)	1.34	1.34	1.30	0.25
Organic matter (%)	1.15±0.015	1.25±0.20	1.89±0.33	<0.0001
Carbon (%)	0.66±0.03	0.73±0.12	1.11±0.20	0.09
Nitrogen (%)	0.06±0.003	0.06±0.009	0.09±0.014	0.10
Phosphorus (ppm)	2.72±0.71	2.80±0.78	3.35±1.15	0.36
Potassium (ppm)	49.25±13.62	38.77±3.99	53.32±11.13	<0.05
Calcum (ppm)	694.45±82.76	220.78±42.81	111.37±29.20	<0.0001
Magnesium (ppm)	217.86±25.30	165.32±24.65	208.73±32.22	0.59
Moisture (%)	1.44	2.00	5.86	
Litter (ton/ha)	8.59±0.82	11.68±1.17	7.53±0.40	<0.0001
Texture	Sand	Sand	Sandy Loam	

3.3.2. Soil electrical conductivity

High levels of soil salinity is one of the main factors that limits the spread of plants in their natural habitats. It is an ever increasing problem in arid and semi-arid regions (Amira, 2011). Electrical Conductivity (EC) testing is a reliable way to assess how salts affect plant growth. The EC of soil is influenced by concentration and composition of dissolved salts. Salts increase ability of a solution to conduct an electrical current. A high EC value therefore indicates a high salinity level. Generally an EC (1:5) water extract <0.15 will not affect plant growth (Apal, 2015).

The mean EC of soils in ASF was 0.035 for Mixed forest zone, 0.024 for Brachystegia forest zone and 0.029 for the Cynometra forest zone. The EC of the soil was significantly different in the three vegetation zones ($p=0.006$). This may be attributed to different soil types dominating these zones. The low concentrations of soluble salts indicate that soils in ASF were less saline.

3.3.3. Bulk density

Soils in ASF had a mean Bulk Density (BD) of 1.4. However, there was no significant difference of BD along the soil profile. Bulk density was also not significantly different across the three vegetation zones. Soil structure, indirectly influences plant growth. The pores are the controlling factors governing water, air and temperature in soil, which in turn, govern plant growth. The hard compact layer impedes root growth. Soil compaction is the process of increasing dry bulk density of soil, reducing the pore space by expulsion of air through applied pressure on a soil body (Tarahaat, 2016).

Bulk density of soil varies due to organic matter content, texture, compaction, and porosity of the soil. Histosols have very low bulk density (about 0.70) and particle density. Bulk density may differ at different depths of soil. In forested mineral soils, bulk density rapidly increased with depth in the surface but remained uniform at depths >20 cm. This is related to distribution of organic matter and compaction. Bulk density tends to increase with depth primarily due to lack of organic matter and aggregation of the soil.

3.3.4. Soil physical properties (color, texture, horizons)

Soil texture of ASF ranged from sandy to sandy loam. Sandy loam soils are dominated by sand particles, but contain enough clay and sediments to provide some structure and fertility. The Brachystegia zone was dominated by white sands with two soil horizons (organic layer and horizon A). The Cynometra zone was dominated by red Magarini sandy loam soils with O and A horizons. Sandy loam soils are capable of quickly draining excess water but cannot hold significant amounts of water or nutrients for plants. Sandy loam soils are often deficient in specific micronutrients and may require additional soil modification to support healthy plant growth (Osman, 2013).

White sandy soils, which dominate the Mixed forest zone, are coarse textured soils (loose and friable); they absorb water rapidly and drain it quickly, and can be worked easily in both moist and dry conditions. Soil in the Mixed forest zone had no definite soil horizons. Such soils are usually poor in fertility and suffer from water scarcity. These soils are characterized by low soil organic carbon, low Cation Exchange Capacity (CEC), high risk of nutrient leaching, low structural stability, and a high sensitivity to erosion and to crusting.

3.3.5. Soil organic matter

Soil organic matter (SOM) comprises of partially disintegrated and decomposed plant and animal residues, and other organic compounds synthesized by soil microbes as decay occurs (SERA, 1995). The level of organic matter in ASF was significantly high in all the vegetation types ($p<0.0001$). Soil organic matter was highest in the Cynometra zone (1.9%); this was followed by Brachystegia zone (1.3%) and Mixed forest zone (1.2%) respectively.

According to Horneck *et al*. (2011), the amount of organic matter on the surface can vary from less than 1.0% in coarse-textured sandy soils to more than 5.0% in fertile soils. The baseline data in ASF show a healthy ecosystem with organic matter levels of 1.1%, 1.3% and 1.9% for Mixed forest, Brachystegia forest and Cynometra forest respectively. Most SOM was found in the zone of maximum biological activity, the topsoil or plough layer. Soil organic matter is a surrogate for soil carbon and is measured as a reflection of overall soil health. When monitored for several years, it gives an indication of whether soil quality is improving or declining. Despite high litter fall in the Brachystegia forest, the SOM was lowest. This can be attributed to low decomposition rate as a result of low soil moisture content (below 1.0%) which hindered soil microbial activities.

Soil organic matter is important to a wide variety of soil chemical, physical, and biological properties. As SOM increases, so does CEC, soil total N content, water-holding capacity and microbiological activity (Horneck *et al*., 2011). Medium levels of SOM have been reported to be desirable for optimal plant growth (UoC, 2015). Other benefits of soil organic matter in the soil include; improved water and nutrient holding capabilities, and better soil structure which enhances root growth and increases aeration. Environmental change however is likely to alter decomposition rates through direct effects on soil biotic activity and indirect effects on litter quality with possible impacts on the global carbon budget and nutrient cycling. Tropical forests like ASF are likely to be more affected by changes in soil water availability (caused by the combined effects of changes in temperature and rainfall). Decline in soil moisture may accelerate forest loss in many areas where water availability is already marginal (Miko and Fischlin, 2015).

3.3.6. Soil pH

The mean pH of soil in ASF was slightly acidic (6.27). The pH was significantly different in the various vegetation types ($p=0.0003$). This can be attributed to difference in soil types in the three main vegetation zones of ASF. The pH in the various vegetation zones was 6.7, 6.2 and 5.8 for Mixed forest, Brachystegia forest and Cynometra forest respectively. The pH of soil does not only affect availability of necessary plant nutrients but also solubility of potentially toxic elements such as aluminum (Al) and lead (Pb). The soil pH measures active soil acidity or alkalinity. Generally, the soil ranged from moderately acidic to slightly acidic. Mineral release is also inhibited by the acidic nature of many tropical soils (UoC, 2015).

3.4. Soil nutrients

3.4.1. Total nitrogen and carbon

Soil analysis results indicated very low nitrogen content ranging from 0.06% in Mixed forest and Brachystegia forest to 0.09% in the Cynometra forest. This could be attributed to slow nutrient release as a result of the dry conditions. Soil moisture was below 2.0% across all the three vegetation zones. The coarse textured soil also could have contributed to leaching of nitrates due to their low adsorption capacity. Over and above, the soil moisture content was low in ASF. This is as a result of the low water holding capacity of sandy and sandy loam soils.

Carbon content was also very low with ranges of 0.66%, 0.73% and 1.11% for Mixed forest, Brachystegia forest and Cynometra forest respectively. Nitrogen and Carbon was however not significantly different across the vegetation zones. The mean Carbon: Nitrogen ratio across the various vegetation zones was 11. Soil C/N ratio is a sensitive indicator of soil quality. This because soil C/N ratio is often considered as a sign of soil nitrogen mineralization capacity. High soil C/N ratio can slow down the decomposition rate of organic matter and organic nitrogen by limiting the soil microbial activities, whereas low soil C/N ratio could accelerate the process of microbial decomposition of organic matter and nitrogen leading to nutrient release (Shunfeng Ge, 2013).

3.4.2. Soil phoshorus

Concentration of Phosphorus (P) in the different vegetation zones was significantly different ($p=0.0003$). The Cynometra and Brachystegia zones recorded the highest P concentration of 3.4 ppm while the Mixed forest zone which is dominated by white sand had a mean P concentration of 2.5 ppm. Phosphorus is essential for root development, production of flowers and fruit. Phosphorus is most available at a pH of about 6.5 in moist warm conditions. Phosphorus is relatively immobile in soil. Phosphorus availability decreases in cool, wet soils. High soil phosphorus combined with P movement from soil into surface waters can cause excessive growth of vegetation, damaging aquatic ecosystems.

Water transport mechanism through the soil and sub-soil properties has been reported to be more important for P leaching (Djodjic *et al*., 2004). This may have attributed to the low P concentration in the forest soil which is dominated by porous dry sand. Although phosphate P is strongly adsorbed in many soils, it may be quickly transported through the soil by preferential flow. Earlier studies revealed that P was very immobile in the top soil but the higher P fixing capacity of the top soil appeared to restrict P mobility (Sinaj *et al*., 2002).

3.4.3. Soil exchangeable bases

The soils in ASF had Calcium ranging from moderate to high concentration. Mixed forest had 694 ppm, while Brachystegia forest and Cynometra forest recorded 220 ppm and 111 ppm respectively. Concentration of calcium was significantly different across the various vegetation types ($p<0.0001$). Calcium is a vital component of cell manufacturing process and improves uptake of other nutrients.

Calcium deficiency occurs in very acidic soils. This explains the low level of Calcium in the Cynometra forest which was moderately acidic. Calcium is rarely deficient when soil pH is adequate. Calcium deficiency can occur at otherwise adequate soil pH values in serpentine soil (high Mg). Similar studies have shown that most exchangeable Calcium was found in top soil with only small amounts in the soil layers deeper than 30 cm (Nykvist, 2013).

Concentration of Magnesium in ASF was high; however concentrations were not significantly different across different vegetation zones. The Mixed forest had the highest level of Magnesium (217 ppm). The Brachystegia and Cynometra forests had concentration ranging from 165 ppm and 208 ppm respectively. Magnesium is a key element in the development of chlorophyll; it is also crucial for seed formation.

Concentration of Potassium was not significantly different across to the three vegetation zones of the forest. Concentration of Potassium was low across the various vegetation zones with Mixed forest, Brachystegia forest and Cynometra forest recording 49 ppm, 38 ppm and 53 ppm respectively. Plants require large amounts of potassium (K), which is sometimes referred to as potash (K2O). It is critical for numerous plant functions and especially aids in hardiness and disease resistance. Potassium is released from rocks and soil minerals as they weather.

3.5. Conclusion

Soil texture of ASF ranged from sandy to sandy loam. The Brachystegia forest was dominated by white sands with two soil horizons (organic layer and horizon A) along the soil profile. Cynometra forest was dominated by red Magarini sandy loam soils with O and A horizons. Soils in the Mixed forest had no definite soil horizons. This was an indication of highly weathered soils. The soil has very low soil moisture content of less than 2.0%. ASF had a mean Bulk Density (BD) of 1.4 which is an indication of a less compacted soil. The Brachystegia forest recorded highest amount of leaf litter in the forest. This could be attributed to the deciduous nature of *Brachystegia speciformis* which leads to massive litter fall during the sampling period which was undertaken in the dry season. Soil organic matter was highest in the Cynometra zone (1.89%); this was followed by Brachystegia zone (1.25%) and Mixed forest zone (1.15%) respectively.

3.6 Recommendation

1. Periodic monitoring of edaphic factors should be carried out and the soil data correlated to vegetation distribution and natural regeneration of the forest to ensure a holistic approach to biodiversity monitoring.

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CHAPTER 4: COMPOSITION AND DISTRIBUTION OF SMALL AND LARGE MAMMALS IN ARABUKO SOKOKE FOREST

J. Nyunja, B. Ogwoka, L. Njeri

4.0 Introduction

Understanding the composition and distribution of species in ecological systems is important for ecosystem planning, and implementation of strategic adaptive management programs in protected areas. The growing impacts of human activities, overexploitation of natural resources, and climate change have adverse effects on mammalian species composition and distribution in dynamic forest ecosystems. Additionally, conservation areas usually undergo several changes in plant biodiversity (Myers *et al.*, 2000), and the changes can have severe effects on the presence of endemic birds (Scharlemann *et al.*, 2004), terrestrial vertebrates (Brooks *et al.*, 2006), or flagship species (Williams *et al.*, 2000).

Arabuko Sokoke Forest (ASF) ecosystem continues to be recognized as a biodiversity hotspot as seen in the recent discovery of a previously un-described species of giant elephant shrew (Rhyncocyon spp.) endemic to ASF (Andanje *et al.*, 2010). The forest is also home to other endemic- species such as the Sokoke bushy-tailed mongoose (*Bdeogaleom nivora*), and the golden-rumped sengi (*Rhynchocyon chrysopygus*). ASF is faced by a myriad of conservation challenges within the forest block and adjacent human settlement areas. This is exacerbated by limitation in available resources for protection and management of the forest resource. This situation calls for priority setting while determining biodiversity research and management interventions geared towards safeguarding this critical ecosystem. To address this limitation, regular assessment of the ecosystem is required so as to ensure that conservation objectives and priorities remain up to date and relevant (Doggart *et al.*, 2006; Amin *et al.*, 2014). Hence, frequent monitoring should be integrated into conservation and management planning of biodiversity hotspots like ASF.

This chapter presents the composition and distribution of small and large mammals in two vegetation types of ASF i.e. Cynometra forest and Brachystegia forest. Information presented in this chapter forms a benchmark for long-term monitoring to ascertain continuous impacts of human activities and climate change on small and large mammals and the overall biodiversity of the forest.

4.1 Materials and Methods

4.1.1 Sampling design

Sampling and data collection was carried out between February and April 2015 using the camera traps methodology. Camera traps are used as a survey tool for medium to large terrestrial mammals, and is more efficient in thick forests (Silveira *et al.*, 2003; Tobler *et al.*, 2008; Ahumada *et al.*, 2011) that are difficult to survey using other methods such as sign surveys. The sign surveys are often biased towards large bodied diurnal species and fail to detect rare and elusive nocturnal species (Srbek-Araujo and Chiarello, 2005). Standardization of camera traps enables classification of species into functional groups such as trophic category, life-history, social structure and body size. The standardization method enables comparison of different mammal communities and species composition in different continents. Hence, the impact of factors including climate change, land use change, and over-exploitation on mammal communities at global, regional and local scales can be compared directly using the standardized techniques (Ahumada *et al.*, 2011).

This survey was conducted within the Cynometra forest and Brachystegia forest (Figure 4.1). One camera grid was placed in the Cynometra forest (the same locations as the 2010 survey) and the other in Brachystegia forest. Survey design at each forest site consisted of cameras systematically spaced at 2 km intervals on a regular 3 x 7 square grid, orientated to available habitat patches. Standardized camera traps were systematically placed at intervals to capture data on both small and large mammals as described in Andanje *et al.*, (2015). This grid spacing resulted in a camera density of one per 4,000ha. Range sizes of the target species investigated within the study are known to be small relative to the sampling regime.

The sampling grids of cameras were positioned in extensive areas of forest and thicket based on habitat and accessibility. ArcGIS 9.3 (ESRI, Redlands, CA USA) software and GPS receivers were used to locate camera sampling unit center points. A single camera-trap was placed within 100 m of each centroid under closed canopy forest or thickets. The cameras were set at a height of 30 - 45 cm, positioned perpendicular to game trails at a distance of 4 - 8 m to obtain full body lateral images of small antelopes and other mammal species. These cameras use an infrared flash to minimize risk of startling animals when they enter the camera view. Each survey was conducted with 20 fully functioning cameras for a minimum of 50 days in order to achieve 1,000 camera-trap days of sampling effort (O'Brien *et al.*, 2003).

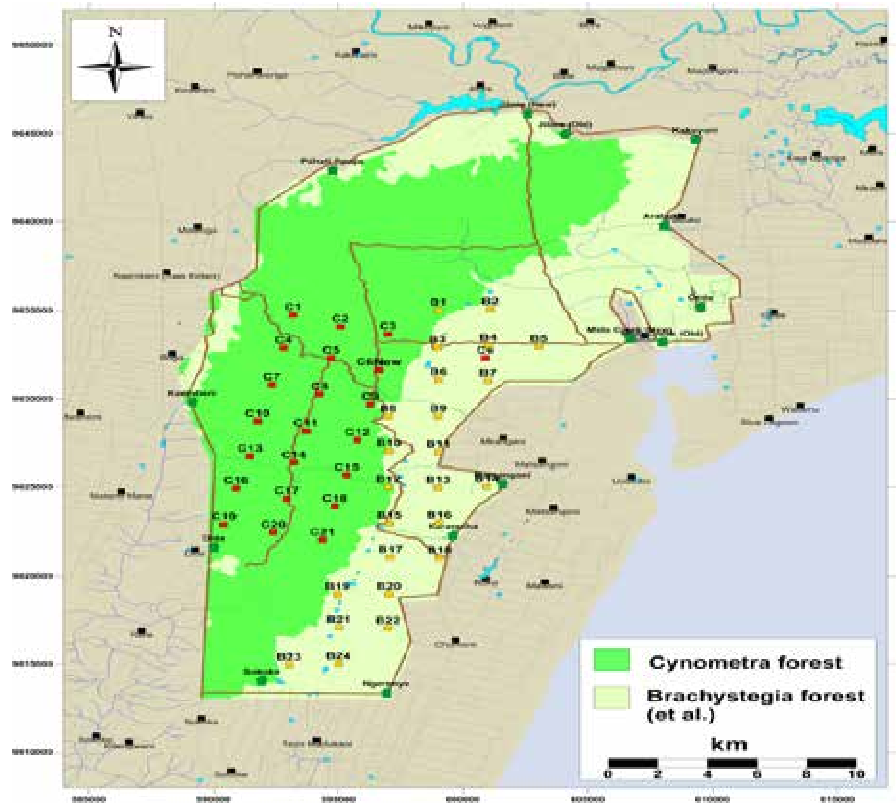

Figure 4.1: Map showing location of camera traps along line transects

4.2 Data analysis

4.2.1 Data compilation and processing

The Picture Image Extraction (PIE) software tool was used to extract meta data from the images gathered by the camera-traps. The camera-trap label, date and time were compiled for each image in an Excel sheet (Microsoft Office Professional Plus, 2010). All photographs were classified by species, and grouped into independent photographic events. An 'event' was defined as any sequence of photos from a given species occurring after an interval of ≥ 60 minutes from the previous images of that species (Bowkett *et al.*, 2008; Tobler *et al.*, 2008; Rovero and Marshall, 2009; Amin *et al.*, 2014).

4.2.2 Species richness

Zoology Society London (ZSL) camera-trap Analysis Package with the "Biodiversity R" package in R software program (Kindt and Coe, 2005) was used to estimate species richness of medium-to-large terrestrial mammals (weighing greater than 0.5 kg) in each forest site. Arboreal species were excluded as they were less likely to be captured by cameras directed at ground level. Species less than 0.5 kg were also excluded because their small size results in reduced and inconsistent capture probabilities. This defined a subset of species of approximately similar detectability provided a consistent measure of mammal species richness for each site which through replicate surveys provides trends in species composition and richness over time. Rarefied accumulation curves were generated for each species in each forest site by randomly re-sampling the data and calculating average number of species expected to be found at a given sampling intensity. This curve reaches an asymptote when all species from the focal group or taxa have been recorded.

For mammal species diversity measures, the Shannon Weiner index (H) (Shannon and Weaver, 1963) and evenness were calculated at each site. This was done using the species daily trapping rate (number of events per day/total number of cameras active on the day).

4.2.3 Species distribution

Single season occupancy analysis (MacKenzie *et al.*, 2006) was used to estimate proportion of area occupied by species in each of the three sampling grids. Occupancy of each species was analyzed separately within the ZSL Camera-trap Analysis Package using the unmarked package in R software (Fiske and Chandler, 2011). Samples (days) were grouped into ten-day sampling occasions to improve detection probability of the rare species and constructed detection (1) / non-detection (0) history for each species per study site. Naıve occupancy (the number of cameras at which each species is detected divided by the total number of operational cameras) was also calculated.

4.2.4 Species abundance

The mean number of independent photographic events per trap day x 100 (trapping rate) was used as the relative abundance index (RAI). The RAI is primarily useful within species comparisons under standardized conditions, but differences in species biology and detectability mean that its use in between species comparisons was limited. The standard error of RAI was calculated as the standard deviation of trapping rate divided by the square root of the number of trap days and applied Wald test for significant difference.

4.2.5 Covariate analysis

To measure effect on species occupancy, data on potential factors influencing species status and distribution were gathered. The data collected included: (a) evidence of tree cutting, slash and burn, livestock grazing, hunting, which were combined to form a composite binary yes or no value of disturbance as a covariate for the occupancy modeling; and, (b) the habitat type. Distance to the boundary of the reserve from each camera was measured using the ruler function on ArcGIS. Distance to the nearest village was measured due to high human population around Arabuko-Sokoke Forest (Figure 4.1).

To prepare data for occupancy analysis the species observations were grouped into 10 day occasion detection (1) / non-detection (0) matrices. Data from the Cynometra forest, Mixed forest, and Brachystegia forest in 2015 were also combined to provide an occupancy estimate for the entire site and improve occupancy estimates for each forest type, especially for species with low encounter rates. The species were selected for further analysis based on their occupancy value for the whole of Arabuko-Sokoke: naive occupancy >0.1, sufficient species detection to reliably obtain occupancy estimates, detection probability >0.1, and a 95% probability that the true species estimate lies within the 95% confidence intervals (Rovero *et al.*, 2014); their body weight, trophic level and conservation status. This was to ensure sufficient spatial coverage and to provide information on poorly known species (Table 4.1). PRESENCE (Version 9.5, Patuxent Wildlife Research Centre, Virginia in USA) was used to analyze the covariate data using a single season model. The occupancy estimates were then tested for significance using a Wald test. Pearson's correlation coefficient was used to test the relationship between occupancy and distance to the forest boundary (km).

4.3 Results and discussion

4.3.1 Species diversity

A total of 32 mammal species were identified in the Arabuko-Sokoke Forest in 2015. The identified mammals were listed by their IUCN status and habitat (Appendx I). Among the identified species included: Sokoke bushy-tailed mongoose (vulnerable); the golden-rumped sengi (endangered) (Table 4.1).

The critically endangered Aders' duiker was only encountered on three occasions. A key finding of the study is the rarity of the Critically Endangered Aders' duiker within Arabuko-Sokoke Forest, which was previously considered to have the largest population of the species (Amin *et al.*, 2014; Andanje *et al.*, 2011). However, with only three events being recorded (two in 2010 and one in 2015); it is clearly at risk of becoming locally extinct.

Table 4.1: Species chosen for the covariate analysis in Cynometra forest and Brachystegia forest

Species	Number of events	Average body mass (kg)	Trophic level	IUCN red list status
Blue duiker	71	5.05	Herbivore	Least Concern
Suni	672	5.2	Herbivore	Least Concern
Sokoke bushy-tailed mongoose	64	1.2	Carnivore	Vulnerable
Four-toed sengi	3553	0.2	Insectivore	Least Concern
Golden-rumped sengi	299	0.54	Insectivore	Endangered
Gambian giant rat	172	0.79	Omnivore	Least Concern

The 27 and 24 mammal species recorded within Brachystegia and Cynometra forests within Arabuko-Sokoke Forest in 2015 contained 7 and 8 terrestrial and forest specialists respectively (Table 4.2). Twenty one (21) out of 27 mammal species in Brachystegia forest and 19 out of 24 in the Cynometra forest were medium-large mammals (>0.5kg) similar to a study conducted by Andanje *et al.* (2010).

Brachystegia forest had the highest mammal diversity (1.56) and evenness (0.48) while Cynometra forest had lower species diversity of 1.23 (2010) and 1.19 (2015) and evenness value 0.43 (2010) and 0.39 (2015). The results indicate a decline in species diversity and evenness within a period of 5 years from 2010 to 2015 (Table 4.2).

Table 4.2: Summary of mammalian animal species encountered in Arabuko Sokoke forest

	Total no. of mammal species encountered	No. of forest specialist species	% medium-large species (>0.5kg)	Species diversity (H)	Evenness
Brachystegia forest	27	7	78%	1.56	0.48
Cynometra forest	24	8	79%	1.19 (yr 2015) 1.23 (yr 2010)	0.39 (yr 2015) 0.43 (yr 2010)

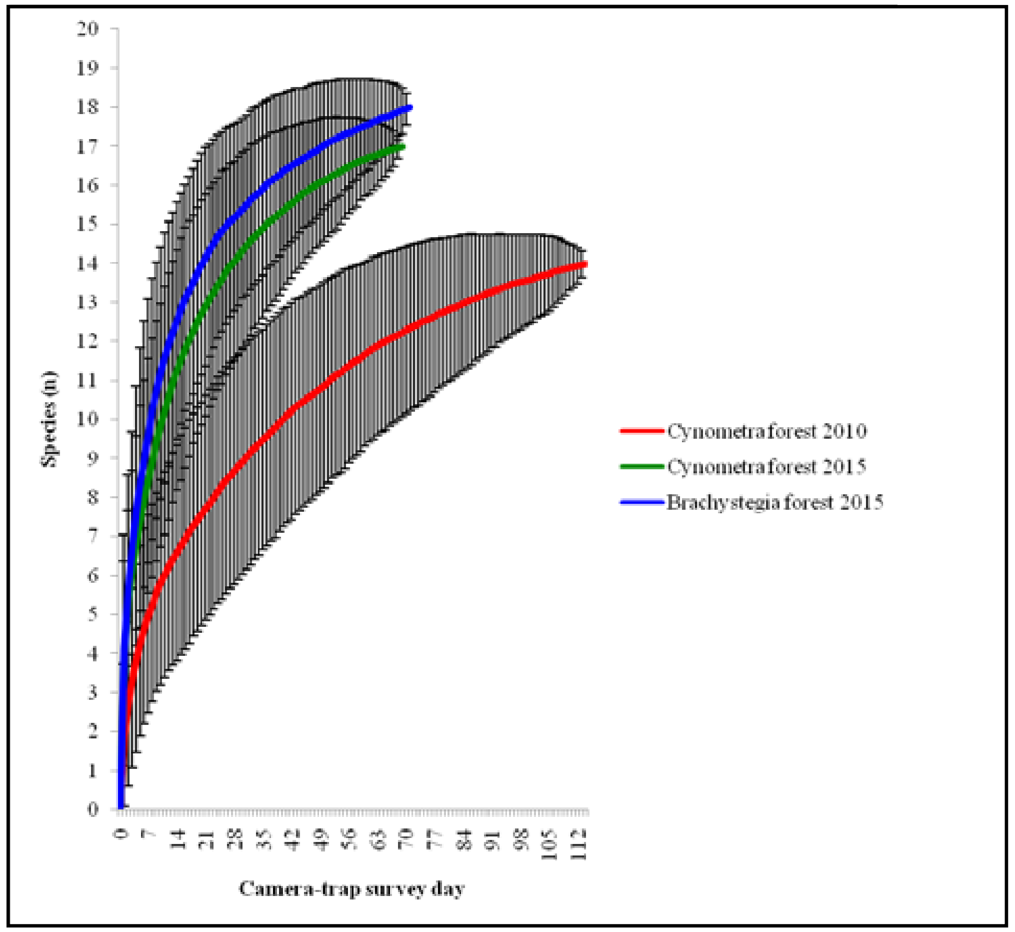

Figure: 4.2 Rarefied species accumulation curve for medium to large forest dependent mammal species in Cynometra forest (2010, 2015) and Brachystegia forest (2015)

4.3.2 Species distribution comparison between 2010 and 2015

The species accumulation curve show that there were more forest dependent mammal species observed in the Brachystegia forest compared to the Cynometra forest (Figure 4.2). The high species diversity (H =1.56) in the Brachystegia forest and higher number of forest dependent mammals indicates that tall trees with open canopy provided a favorable environment for mammals compared to the Cynometra forest. The thick canopy and undergrowth within the Cynometra forest was less preferred by mammals.

Suni were the most widely distributed forest antelope species, detected by all fully operational camera traps with naive occupancy =1 (SE=0) in both forest types (2015). Estimate for the Cynometra forest 2010 survey was only slightly lower =0.95 (SE=0.05); there was no significant difference in occupancy estimates over the 2010 - 2015 time period (p=0.32).

The blue duiker (*Philantomba monticola*) in Brachystegia forest 2015 was only encountered 17 times at 2/24 camera traps, both of which were on the border of Cynometra forest. There was no significant difference in occupancy over the 2010 - 2015 time period (p=0.96).

Harvey's duiker (*Cephalophus harveyi*) was detected infrequently with a maximum of seven independent photographic events in the Cynometra forest habitat (2010). This resulted in all sites having unreliable occupancy estimates. Naive occupancy was =0.1 in Cynometra forest 2010, =0.21 in Brachystegia forest 2015 and =0.2 in Cynometra forest 2015.

Common duiker was only photographed in the Brachystegia forest with only five independent photographic events. Naive occupancy was =0.1.

The Critically Endangered Aders' duiker was only photographed twice at two different cameras in Cynometra forest (2010) and once in 2015. There were no records yet from the Brachystegia forest grid.

Four toed sengi (*Petrodromus tetradactylus*) had the largest increase in occupancy within ASF over 2010-2015 (p=0.01). Brachystegia forest had highest species occupancy (=0.91, SE=0.06). The pairwise comparison was marginally significant between the two forest habitats in 2015 (p=0.07). Golden-rumped sengi had a significant increase in occupancy within the forest between 2010 and 2015 (p=0.01). Distribution within the Brachystegia forest (=0.68, SE=0.11) whilst being higher than the Cynometra forest in 2010 was significantly lower than Cynometra forest in 2015 (p=0.01).

Sokoke bushy-tailed mongoose was recorded for the first time in 2015 surveys. The species was relatively evenly distributed within the Brachystegia forest, and was photographed at 58% of camera traps with a modeled occupancy of 0.58 (SE=0.12). This observation emphasizes the importance of the Brachystegia forest in providing suitable and preferred habitat for the vulnerable Sokoke bushy tailed mongoose. However, due to only two events being recorded at 2/21 sites in Cynometra forest (both on the border of the Brachystegia forest), occupancy estimates were unreliable. Naive occupancy was =0.05. Differences in occupancy between the two forests in 2015 were therefore significant (p=0.01).

4.3.3 Species abundance

Suni was the most frequently recorded forest antelope species in Arabuko-Sokoke Forest with respective Relative Abundance Index (RAI) values in 2010 and 2015 of 24.18 (SE=1.24) and 22.37 (SE=1.28) respectively in Cynometra forest camera grids. Suni was more abundant in the Brachystegia forest (RAI=33.83, SE=2.19) (Figure 4.3). There was a significant difference in RAI between the two habitats (p=0.01).

Blue duiker was the second most frequently encountered forest antelope species in the forest. It was less frequent in more open Brachystegia forest (2015) (RAI=1.68, SE=0.49) compared to the Cynometra forest (2015) (RAI=4.71, SE=0.62, p=0.01). Harvey's duiker was photographed in all three transects with lowest trapping rate in 2015 Brachystegia forest grid (RAI=0.33, SE=0.18) and highest in 2015 Cynometra forest grid (RAI=0.46, SE=0.20) which represents an increase in trapping rate from the 2010 survey (RAI=0.35, SE=0.13). However, none of the trapping rates were significantly different among three surveys (p=0.64) between Cynometra forest in 2010 and 2015, and p=0.63 between Cynometra and Brachystegia forests in 2015.

Common duiker was observed for the first time in ASF in 2015 within Brachystegia forest (RAI=0.34, SE=0.19), but was not recorded in Cynometra forest. Aders' duiker was the least frequently recorded forest antelope species, and was only observed in the Cynometra forest on one occasion with no significant change in trapping rate between 2010 (RAI=0.10, SE=0.07) and 2015 (RAI=0.10, SE=0.10, p=0.32), despite a much larger survey in 2015 covering the two major forest habitats.

Cynometra forest habitat contained the greatest relative abundance of duiker species, with an increase in abundance of both Harvey's and blue duiker in the 2015 survey compared to 2010. However, Suni were the most abundant forest antelope species in both Brachystegia and Cynometra forests (Figure 4.3).

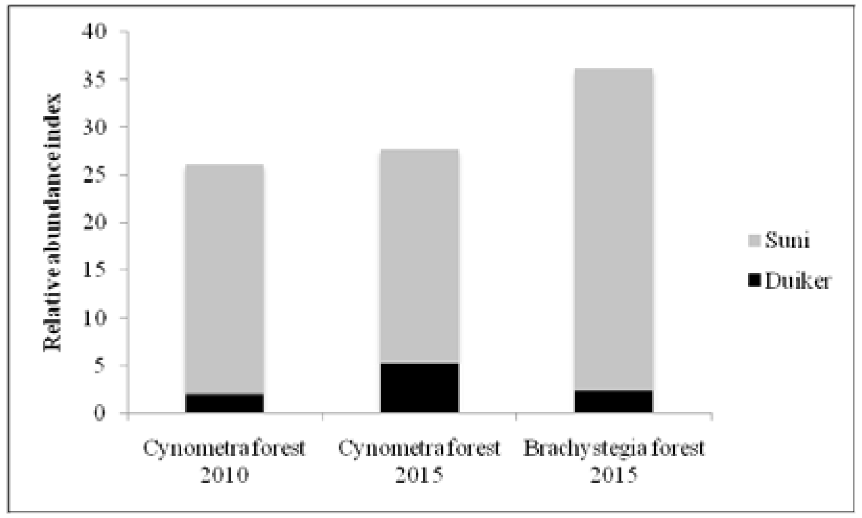

Figure 4.3: Relative abundance index (trapping rate) of Suni compared to all duiker species in the Cynometra and Brachystegia forest camera grids

Four-toed sengi showed the largest increase in trapping rate of all the species recorded in the surveys, with a 49-fold increase between 2010 and 2015 in Cynometra forest (RAI=3.8 [SE=0.39] and 182.06 [SE=4.32], respectively). The trapping rate in Brachystegia forest (2015) was 140.43 (SE=5.04) (Table 4.4). Both increases were statistically significant (p=0.01), between habitats and the years.

4.3.4 Disturbance

Blue duiker (p=0.04) and golden-rumped sengi (p=0.02) had higher occupancy in undisturbed sites compared to disturbed sites (Table 4.5). However, none of the other species displayed any significant differences due to disturbance. The Sokoke bushy-tailed mongoose was not significant (p=0.17) at 95% confidence interval, showing a trend for preferring disturbed sites, but this most likely reflects their preference for more open habitats with Cynometra forest (the more closed habitat) having 4/20 camera trap-sites recorded with signs of disturbance, and Brachystegia forest (the more open habitat) having 13/21 camera trap sites recorded in areas with signs of disturbance.

Blue duiker is known to prefer more dense undergrowth (Hart, 2013b). This is supported by the highly significant correlation between blue duiker occupancy and distance to the boundary, their preference for the more undisturbed Cynometra forest (where they are relatively evenly distributed) and their absence from the Brachystegia forest. There is however evidence that duiker species can increase in degraded forest as it provides more food sources for forest antelope species (Topp-Jorgenson *et al.*, 2009). Blue duiker is also more resilient to hunting pressures than larger duiker species, and able to thrive near human populations (Hart, 2013b).

The golden-rumped sengi also showed a significant increase in trapping rate in Cynometra forest between 2010 (RAI=1.49, SE=0.27), and 2015 (RAI=13.04, SE=1.14, p=0.01). There was no significant difference in trapping rates between the two habitats in 2015 (p=0.60). These findings show that the Blue Duiker and the Golden rumped Sengi prefer undisturbed habitats.

The Sokoke bushy-tailed mongoose had a low trapping rate in the Cynometra forest in 2015 (RAI=0.25, SE=0.14). In comparsion, the Brachystegia forest had a much higher trapping rate which was significantly different to the Cynometra forest (RAI=5.50,SE=0.95,p<0.01). The Sokoke bushy-tailed mongoose preferred the disturbed open habitats in the Brachystegia forest.

Table 4.4: Occupancy estimates for Cynometra and Brachystegia forests grids (2015) with habitat type as a covariate

Species	Occupancy (±SE) Cynometra forest	Occupancy (±SE) Brachystegia forest	Wald test p-value (Cynometra 2015-Brachystegia 2015)	Preferred habitat
Blue duiker	0.57 (±0.11)	0.13 (±0.09)	<0.01	Cynometra
Four-toed sengi	0.96 (±0.04)	0.88 (±0.08)	0.39	No preference
Gambian giant rat	0.43 (±0.10)	0.80 (±0.11)	0.01	Brachystegia
Golden-rumped sengi	1 (±0)	0.71 (±0.12)	0.01	Cynometra
Sokoke bushy-tailed mongoose	0.13 (±0.07)	0.57 (±0.13)	<0.01	Brachystegia
Suni	1 (±0)	0.95 (±0.08)	0.55	No preference

4.3.5 Habitat

Blue duiker (p=0.01) and golden-rumped sengi (p=0.01) both had higher occupancy in the Cynometra forest, whereas Gambian giant rat (p=0.01) and Sokoke bushy-tailed mongoose (p=0.01) had higher occupancies in the Brachystegia forest. However, both suni (p=0.54) and the four-toed sengi (p=0.39) displayed no habitat preference (Table 4.5).

Table 4.5: Occupancy estimates for Cynometra and Brachystegia forests (2015) with human disturbance as a covariate

Species	Undisturbed Occupancy (±SE)	Disturbed Occupancy (±SE)	Wald test p value (Undisturbed-Disturbed)
Blue duiker	0.50 (±0.11)	0.19 (±0.10)	0.04
Four-toed Sengi	0.96 (±0.04)	0.88 (±0.08)	0.39
Gambian Giant rat	0.55 (±0.10)	0.61 (±0.12)	0.75
Golden-rumped Sengi	1 (±0)	0.74 (±0.11)	0.02
Sokoke bushy-tailed mongoose	0.22 (±0.09)	0.43 (±0.13)	0.17
Suni	1 (±0)	0.95 (+0.08)	0.54

4.3.6 Distance to the reserve boundary

Blue duiker occupancy had a strong positive correlation (0.995, p=0.01) to distance to protected area boundary, as did the golden-rumped sengi (0.903, p=0.01) and suni (0.764, p=0.01) (Figure 4.4). Blue duiker is known to prefer more dense undergrowth (Hart, 2013b). This is supported by the highly significant correlation between blue duiker occupancy and distance to the boundary, their preference for the more undisturbed Cynometra forest (where they are relatively evenly distributed) and their absence from the Brachystegia forest. There is however evidence that duiker species can increase in degraded forest as it provides more food sources for forest antelope species (Topp-Jorgenson *et al.*, 2009). Blue duiker is also more resilient to hunting pressures than larger duiker species, and able to thrive near human populations (Hart, 2013b). The increase in occupancy of the 3 mammal species (Blue duiker, golden-rumped sengi and the suni) as the distance from the reserve boundary increased corroborates their preference for the undisturbed Cynometra forest.

The Suni, which increased noticeably in Brachystegia forest, displayed no habitat preference and high occupancy regardless of distance to the boundary. This would not be expected if hunting pressure was the cause for this difference between Suni and Blue duiker as the methods used such as snares and net driving do not discriminate between the two species (Nielsen, 2005). Observed results suggest that another factor was affecting blue duiker distribution but not the Suni'.

The Gambian giant rat (-0.999, p=0.01) and Sokoke bushy-tailed mongoose (-0.997, p=0.01) occupancy had very strong negative relationship with distance to the boundary (Figure 4.6). This further supports the findings for occupancy related to habitat preference and disturbance, as the Cynometra forest camera traps were on average 3.38 km away from the boundary compared to 2.04 km for Brachystegia forest with more evidence of disturbance being recorded within the Brachystegia forest which is closer to the boundary.

The Sokoke bushy-tailed mongoose displayed a preference for the more disturbed Brachystegia forest. This would explain the negative correlation in occupancy with increasing distance from the boundary, as the habitat becomes more unfavorable for the mongoose with a closed canopy being associated with the less disturbed Cynometra forest. The Sokoke bushy-tailed mongoose are however at risk of being snared in the more human disturbed areas, as the traps placed capture a wide range of species (Nielsen, 2005). Repeat studies would be required to monitor population trends of this little studied endangered golden rumped sengi and the vulnerable Sokoke-bushy tailed mongoose.

Four-toed sengi had a marginally positive correlation with distance to protected area boundary (0.272, p=0.08). The sengi species had different responses to habitat type, disturbance and distance to the boundary. The golden-rumped sengi which is a target in the bush-meat trade (Kanaga, 2002) was more sensitive to these factors, with significantly higher trapping rate and occupancy in the denser Cynometra forests (their preferred habitat (Fitzgibbon, 1995), compared to the more open and disturbed Brachystegia forest. The four-toed sengi had high trapping rates and occupancy in both forests; when these measures are congruent it allows large differences to be considered meaningful (Amin *et al.*, 2014). The highest trapping rate and occupancy was in the Cynometra forest, which is the preferred habitat for the species (Fitzgibbon, 1995). However, the four-toed sengi also occurred at similar occupancy and trapping rate in the Brachystegia woodland reportedly their least preferred habitat (Rathbun, 2013). This observation is likely due to their less specific habitat requirements compared to the golden-rumped sengi (Fitzgibbon, 1995).

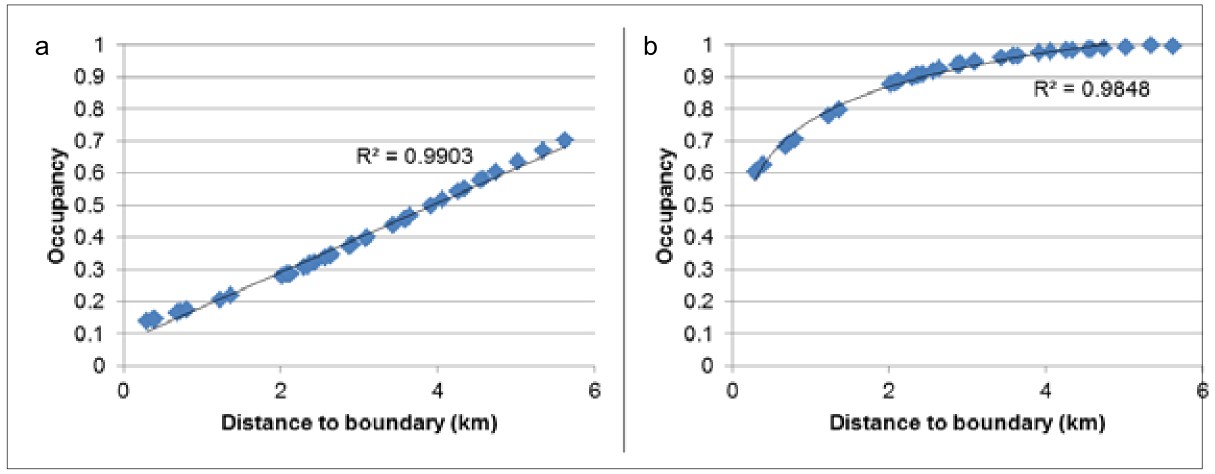

Figure 4.4: Relationship between distance to reserve boundary and occupancy for (a) blue duiker and (b) golden-rumped sengi in Arabuko-Sokoke Forest

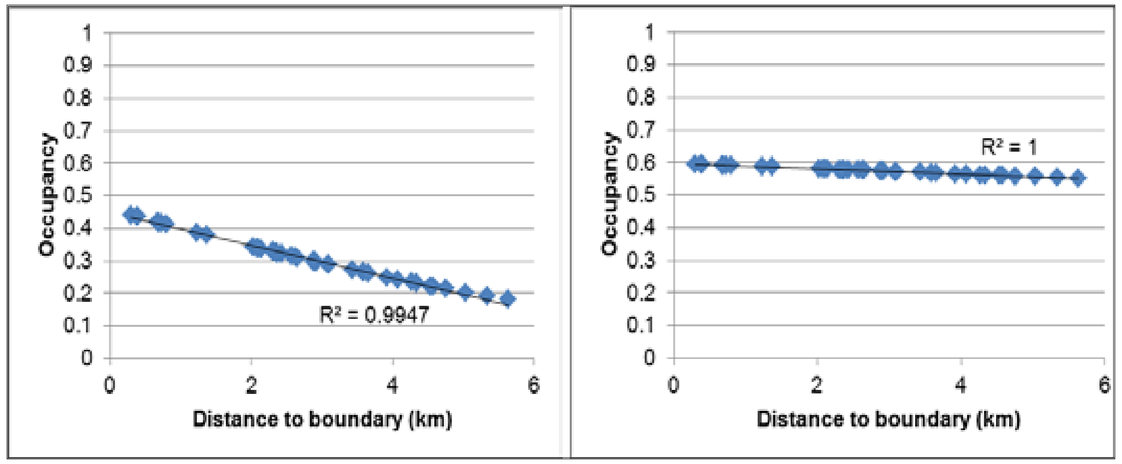

Figure 4.5: Relationship between distance to reserve boundary and occupancy for (a) Suni and (b) four-toed sengi in Arabuko-Sokoke Forest

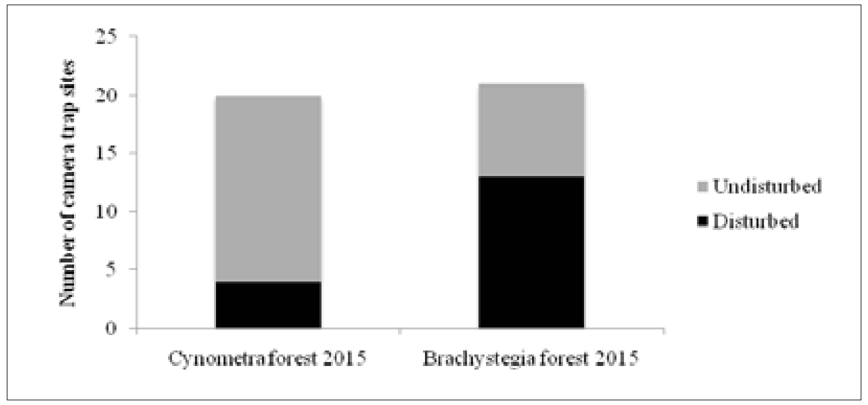

Figure 4.6: Number of camera trap sites in the Brachystegia and Cynometra forests (2015), recorded as having evidence of human disturbance

4.4 Conclusions and Recommendations

1. There is evidence of continued population reduction of the critically endangered Aders' duiker. The species is at risk of becoming locally extinct.
2. There is need to enhance management and conservation of the Brachystegia forest habitat since it supports more animal species in Arabuko Sokoke.
3. Arabuko Sokoke Forest is still a biodiversity hotspot and habitat for the endangered small mammals such as the golden-rumped sengi and the vulnerable Sokoke bushy tailed mongoose. It is also a habitat of flagship species like the African elephant among other large mammalian species.
4. There is need to enhance regular biodiversity monitoring in ASF to ascertain continuous impacts of human activities and climate change in the ecosystem.

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CHAPTER 5: BIRDS OF ARABUKO SOKOKE FOREST

R. Mulwa and J. Mutunga

5.1 Introduction

Arabuko Sokoke Forest (ASF) is the largest remnant of the fragmented coastal forests of East Africa (Bennun and Njoroge, 1999). It has been ranked by BirdLife International as the second most important forest for bird conservation in mainland Africa (Collar and Stuart, 1988). Arabuko Sokoke Forest is the Seventh of the 60 Important Bird Areas (IBAs) in Kenya. Important Bird Areas are selected for holding bird species that are threatened with extinction, have highly restricted distributions, or are characteristic of particular biomes (Bennun and Njoroge, 1999). The forest is home to six globally-threatened birds species (Sokoke Scops Owl, Clarke's Weaver, Sokoke Pipit, Amani Sunbird, Spotted Ground Thrush and the East Coast Akalat). Five out of the seven species in the East African Coastal Forests Endemic Bird Area, occur in the forest. The Clarke's Weaver is known only from Arabuko–Sokoke and Dakatcha woodland (IBA 9), while the Sokoke Scops Owl is only found in this forest and one other site in North-East Tanzania (Kelsey and Langton, 1984). More than 230 bird species have been recorded in the forest which includes 25 of Kenya's 30 African East Coast biome species (Fanshawe, 1995).

5.1.1 Role of Birds Studies in Biodiversity Management

Richness and composition of birds within a forest give an indication of the ecosystem's overall value for the preservation of biological diversity. The avifauna community in a forest can offer a management tool for monitoring environmental change and the impact of habitat alteration. Birds play major roles in many ecosystem through functions such as pollination and seed dispersal. Birds also act as an indicator on health status of nature and the environment among local communities and young people (Diamond and Filion, 1987; Fanshawe and Bennun, 1991).

Birds offer innumerable opportunities for use in biodiversity priority setting. Birds occur diversely in many ecosystems and are easy to survey and monitor, and any changes in their numbers or distributions can be easily assessed by forest managers or local communities at very low input and sustainability costs. Birds respond very rapidly to changes in their environments thus making it easy to determine changes in forest structure that would otherwise be extremely difficult or would take too long for humans to detect (Matiku and Mulwa, 2006).

5.1.2 Threats to Birds of Arabuko Sokoke Forest

Birds of the coastal forests in Kenya increasingly face many conservation threats (Muoria *et al.*, 2013). Species population studies indicate that bird species are very specific in where they occur and what they need for survival (Kelsey and Langton, 1984; Lawton *et al.*, 1998). For instance, the Sokoke Scops Owl population is highly dependent on *Brachylaena huillensis* (Virani, 1994) which is important for nesting holes, and Cynometra, which is important for perching sites; the Spotted Ground Thrush prefers shady areas with thick leaf litter and low density of saplings describing a typically natural undisturbed forest. Britton and Britton (1978) showed that the entire Amani Sunbird population is confined only to the Brachystegia woodland. The East Coast Akalat prefers shady and fairly dense sites in Cynometra and Afzelia forests (Matiku, 1996).

A study by Bennun and Waiyaki (1991) demonstrated that distribution and abundance of bird communities correlates positively with habitat quality. Further, Britton and Zimmerman (1979) showed that bird distribution was habitat specific and populations were higher in the healthier sections of the vegetation types where birds were recorded to be present. As forest disturbance increases, specialists become scarce and forest generalists increase, as is the case with secondary forests. For instance, Oyugi (2005) concluded that Amani Sunbird *Hedydipna pallidigastra* is solely dependent on high abundance of *Brachystegia spiciformis*, that a slight change in the woodland results into immediate adverse effects on the species population dynamics.

5.1.3 Objectives of the Survey

This survey was carried out in Arabuko Sokoke Forest in March 2015. The purpose of the study was to address the specific objectives drawn by the biodiversity component of the Kenya Coastal Development Program (KCDP), which sought to:

- Update the checklist of birds of Arabuko Sokoke Forest Reserve
- Determine, assess bird species of conservation concern in ASF
- Determine, assess how birds can be integrated as a management tool for assessing health status of the forest

5.2 Materials and Methods

5.2.1 Sampling Design and Strategy

This study covered three major vegetation zones of Arabuko Sokoke Forest: Brachystegia forest; Cynometra forest and Mixed forest. Distance sampling using point counts was adopted. The technique is most ideal in forest habitats and facilitates easy count of all birds seen or heard from a single point. Repetition in a series of points enables assembling of a list of species present in the area (Bibby *et al.*, 2000). It allows easy location of points systematically compared with transects because it is not hindered by absence of routes and well-spaced sampling points provide more representative data than transect. This method allows inferences to habitat selection and preferences of individual bird species or communities.

The counting points were located systematically within the three 500m wide Permanent Sampling Plots (PSPs). The points were located 200 m apart and the counts lasted for ten minutes as recommended by Bibby *et al.* (2000). The points were placed along the center of each PSP and 50m perpendicular to the central route in alternate sides to allow random coverage of the sampled area. A total of 67 points were surveyed (Appendix III). The first 60 located within the first two PSPs near the road to the Viewpoint from Malindi Road, and seven points were surveyed in the PSP near the road to Jilore.

5.2.2 Data Collection and analysis

Surveys were conducted in the morning (07.00-11.00 hours) and in the afternoon (04.00-05.30 hours). Birds were recorded within a 50 m radial distance from the center of each sampling point and the observations lasted for 10 minutes. Each sampling point was surveyed twice daily (mornings and afternoons). Information recorded included: species name; number of individuals seen or heard; the radial distance; bird activity; perch height above ground; and nature of bird-plant interaction. The survey was conducted by two observers with the aid of binoculars and regional bird guides (Zimmerman *et al.*, 1996; Stevenson and Fanshawe, 2003); all points were marked using GPS. The survey took place between 6th and 12th March 2015. The data was processed using Excel and statistical analysis conducted in R2.11.1.

5.3 Results and Discussion

5.3.1 Bird Community Composition

Results of non-metric multidimensional scaling (NMDS) show that bird communities at the three sites were distinct. In particular, the bird community in Cynometra woodland was much more distinct from Mixed forest and Brachystegia woodland (Figure 5.1). A total of 371 birds were recorded, which included globally threatened species. Amani sunbird (*Anthreptes pallidigaster*) was encountered in both the Brachystegia and Mixed forests. East Coast Akalat (*Sheppardia gunningi sokokensis*) was encountered in the Mixed forest.

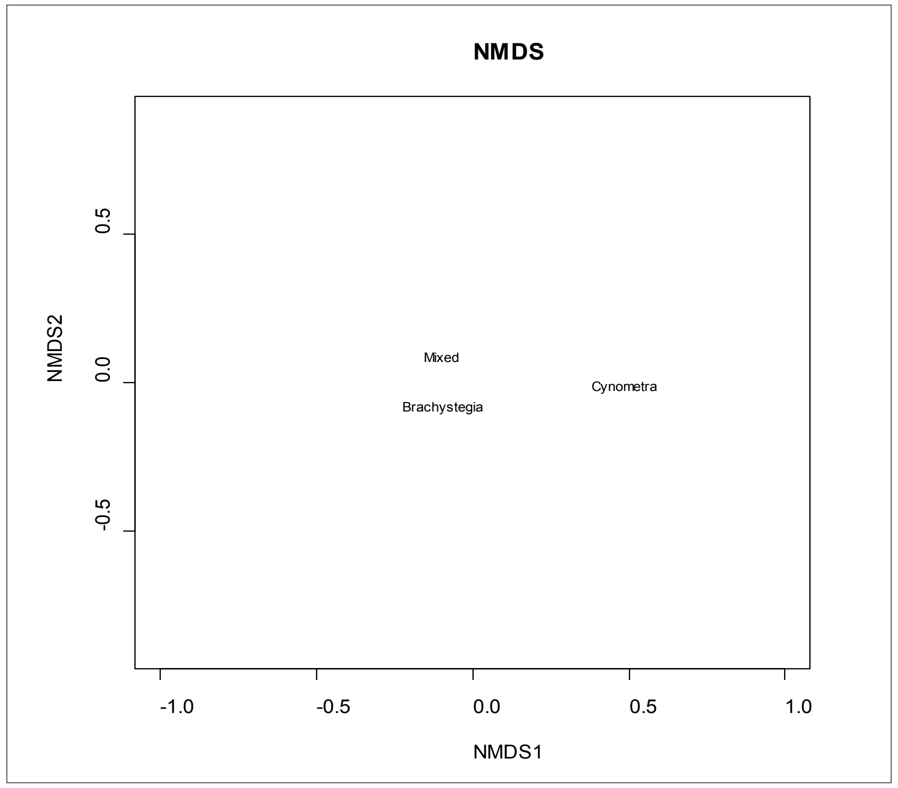

Figure 5.1: *Bird community assemblage across the three vegetation sites*

5.3.2 Abundance of all Bird Species

There was a significant difference between the combined abundance of all bird species recorded within the three sites ($F_{(2, 64)} = 3.25$; $p = 0.045$). Cynometra woodland had significantly lower abundance while Brachystegia woodland reported the highest abundance (Figure 5.2).

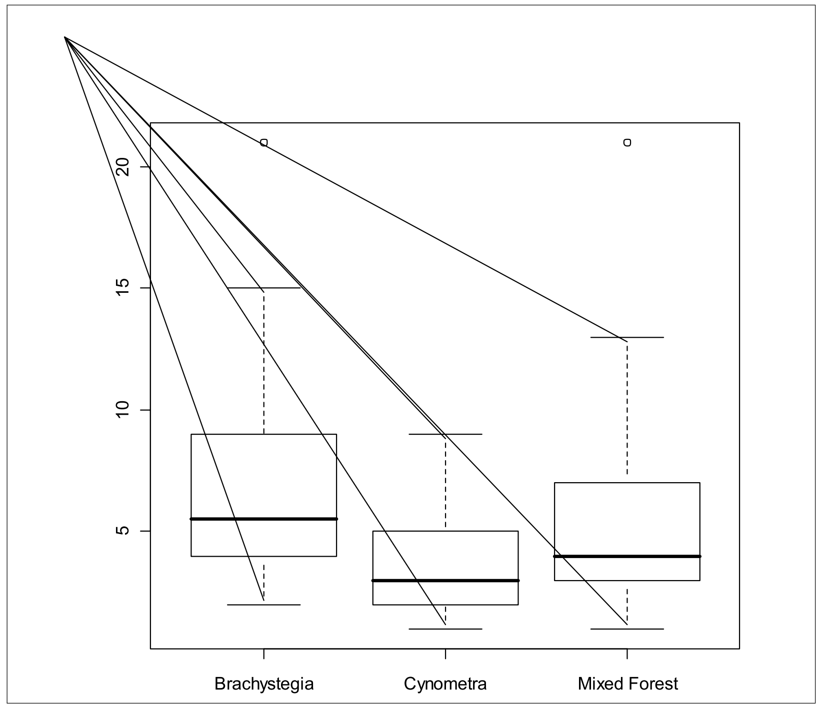

Figure 5.2: *Differences in bird abundance for Brachystegia, Cynometra, and forest sites*

5.3.3 Species Richness

The bird species richness for the different sites showed significant difference ($F_{(2, 64)} = 4.71$, $p = 0.012$). The pattern for species richness was consistent with that of abundance with the Cynometra woodland having the lowest and Brachystegia the highest species count respectively (Figure 5.3). Overall, 36 bird species within 17 families were recorded during the sites survey. Appendix IV shows a checklist of all bird groups encountered during the study across the surveyed sites.

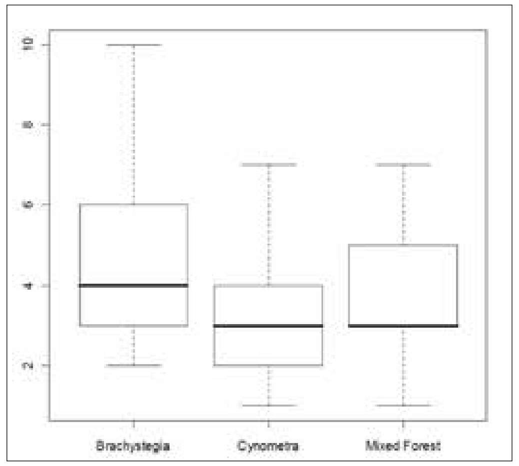

Figure 5.3: *Differences in species richness for Brachystegia, Cynometra, and Mixed forest sites*

5.3.4 Species Diversity

The ANOVA results for the Shannon Weiner Diversity Index (H') obtained from various sampling points showed a significant difference between the three vegetation sites. Cynometra and Mixed forests registered lower scores than Brachystegia forest ($F_{(2, 64)} = 3.288$, $p = 0.04$) (Figure 5.4). The bird community in the Brachystegia forest was more diverse compared to Cynometra and Mixed woodlands that recorded almost equal diversity score (Figure 5.4).

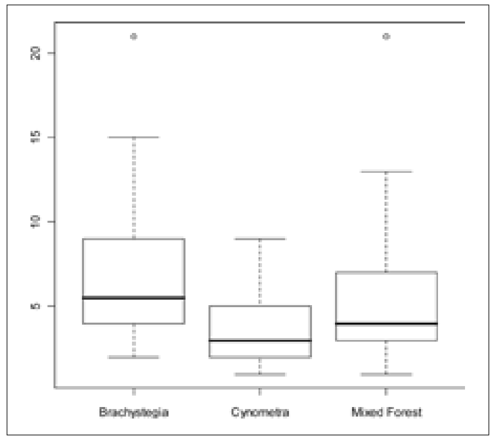

Figure 5.4: *ANOVA showing differences in species diversity index*

5.3.5 Presence of Feeding Guilds across Survey Sites

The survey registered at total of five feeding guilds across the three vegetation zones (Figure 5.5). Brachystegia woodland had the highest (five feeding guilds) among the survey sites, while the Cynometra had the least number (insect/seed and nectarivores) of the feeding guilds. Insectivores and nectarivores occurred in all the sites.

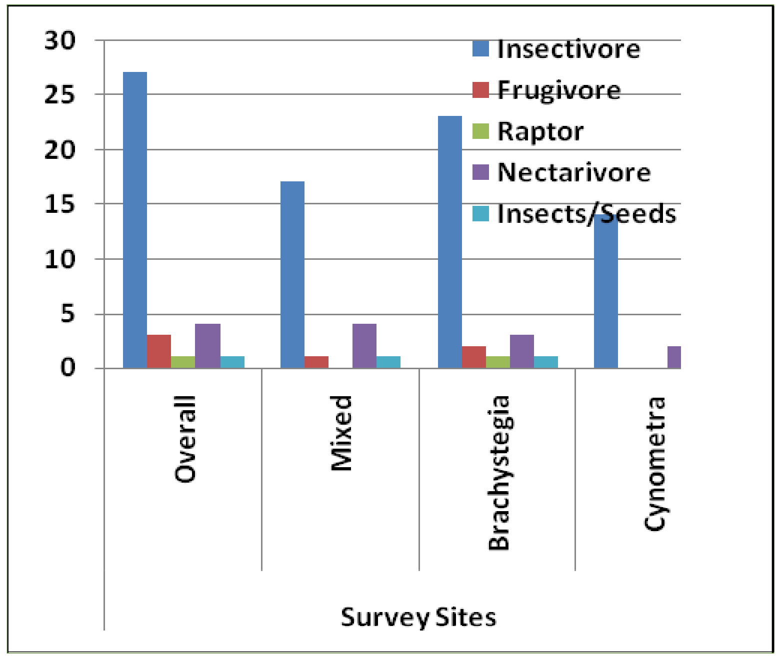

Figure 5.5: Feeding Guilds as represented in various survey sites

5.3.6 Bird Species Composition

It is evident from the findings that bird composition is not homogenous across the three vegetation zones within Arabuko Sokoke. The sites present unique habitat features for the avifauna based on the plant species composition and vegetation structure (canopy height, underbrush, litter cover). The three habitat types are distinguished by unique dominant plant species and structure. Brachystegia forest occurs as open woodland and on "deep, loose, light grey to buff, medium to coarse sand" soils (Britton and Zimmerman, 1979). The open woodland (mainly *Brachystegia spiciformis*) allows for growth of shrubs, grass, and herbs and epiphytes. The Cynometra comprise of forest and thickets on a red soil; while Mixed forest has a diverse composition of plant species that are continuous, dense, and tall on sandy soil. The difference in habitat formation and plant composition in different forest types has an influence in foraging behaviors, and exploitation of habitat resources by different bird guilds, especially among the specialists. For instance, the presence of *Brachystegia spiciformis* influences occurrence and foraging of Amani sunbird (*Hedydipna pallidigaster*). Canopy heights also influence occurrence of the sunbird (Oyugi *et al.,* 2011).

5.3.7 Bird Abundance and Species Richness

This study shows that Brachystegia woodland had a relatively higher bird species abundance and richness; perhaps attributable to the high habitat heterogeneity which provides keystone structures at this site. Multiple occurrence and large flocks of the Retz and Chestnut-fronted Helmet-Shrikes at this site boosted bird abundance.

Species detection may not be disregarded as having played a role but the overriding differences in the pattern of abundance and richness during the site surveys was largely a function of habitat character and quality. Brachystegia has been foci for avifaunal research on species conservation and avi-tourism tour guiding along the East Africa Coast. It is described as a habitat stronghold for the Amani Sunbird. Such a habitat specialist can be an ideal indicator species for establishing status of habitat health in terms of quality, disturbance and degradation. During the survey of 6th-12th March 2015, the East Coast Akalat was not recorded in the Brachystegia woodland but in the Mixed forest. The Akalat is a shy and elusive coastal endemic bird species that nests on the ground with adequate litter cover (Matiku, Bennun and Nemeth, 2000).

5.3.8 Species Diversity and Feeding Guilds

Species detection was relatively higher in the Brachystegia forest. Some of the key species recorded at this site include; Ashy, Pale, and Paradise Flycatchers, Common Scimitarbil, Eastern Nicator, Eurasian golden oriole and Little Sparrow Hawk. Species recorded in other sites include: Purple-banded Sunbird, Little-speckled woodpecker, Green Barbet and East Coast Akalat in the Mixed forest; and Slate-collared Boubou in the Cynometra woodland. Clearly, insectivores had relatively higher abundance among the feeding guilds. Studies on insect population in ASF have listed high diversity lists (e.g. Banks *et al.*, 2010); thus, abundance of food to sustain the diverse number of the insectivore birds. Actually, in the area there is reliance on butterfly farming as an income generating activity.

5.4 Conclusion and Recommendations

Arabuko Sokoke Forest remains home to a unique and ecologically adapted avifauna. Some of the East Africa Coastal endemic bird species of conservation concern notably, Amani Sunbird and East Coast Akalat have been recorded in some locations within Brachystegia and Mixed forests. Birds showed distinctive distributions among the three habitat types, with the Brachystegia woodland holding the richest avifauna.

This study was conducted for a period of six days during a dry season (March 2015). Subsequent studies should consider both dry and wet seasons to capture both spatial and temporal variations in bird community distribution.

The quality of the forest habitats for bird species remains the most important factor in supporting avian diversity in ASF. Best practices of forest management that reduce forest degradation and enhance habitat quality should be embraced. A long term monitoring scheme for assessment of trends in bird community assemblage in various vegetation zones within ASF will create a database that would inform sustainable management of the ecosystem. Indeed several birds and biodiversity monitoring initiatives exist within ASF; however they are often un-harmonized and inconsistent. Harmonization of all on-going long term bird and biodiversity monitoring initiatives within ASF and development of proper data sharing platform is recommended. This will help maximize institutional synergies in terms of capacity and resources.

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CHAPTER 6: AMPHIBIANS AND REPTILES OF ARABUKO SOKOKE FOREST

J. Nyamache and P. K. Malonza

6.0 Introduction

In Kenya there has been past studies aimed at understanding reptile and amphibian species diversity and distribution in Key Biodiversity Areas (KBAs). Past herpetological studies have been undertaken in diverse forest ecosystems such as Arabuko Sokoke Forest (Drewes, 1992; Chira, 1993); Lower Tana River forests (Malonza *et al.,* 2006); Kenya highland forests (Lötters *et al.,* 2006); Taita Hills (Malonza *et al.*, 2010), Kitobo forest (Malonza *et al.*, 2011), Mt. Kenya forest (Malonza, 2016). Herpetological studies in forest ecosystems continue to gain prominence because forests are refuges for endemics and/or range-restricted species.

Arabuko Sokoke Forest (ASF) has diverse habitat types including different forest vegetation types, bushlands, and wetlands that undoubtedly support diverse populations of amphibian and reptile species. Arabuko Sokoke Forest is among the top three reptiles and amphibian species rich areas in Kenya. Others are Shimba Hills National Reserve, Kakamega Forest and Taita Hills. There is however limited information on herpetofauna species endemic to ASF and yet the forest supports a number of coastal biome species (Howell, 1993). Presence of diverse reptiles and amphibians are indicators of healthy forest ecosystem. Better understanding of their distribution and diversity in any given forest ecosystem is therefore important in formulating habitat and species conservation action plans.

This study aimed at establishing herpetofaunal diversity within ASF as a basis for future assessments. The specific objective was to determine the spatial distribution, abundance and diversity of herpetofauna within the forest.

6.1 Sampling design

Data on the spatial distribution, abundance and diversity of amphibians and reptiles was collected in eight transects of one kilometer in length. The GPS coordinates and their corresponding elevations were taken in the sites sampled. Recording of amphibians and reptiles used different methods to achieve maximum detection rate as follows:

i. *Time-limited searches (TLS):* This procedure involved quietly walking slowly for an hour during the day time mainly in the morning and/or late afternoon when herpetofauna are most active, and recording all individuals found within different micro-habitats such as on forest floor, debris, under decomposing logs, on trees or shrubs, grass tussocks. It also involved digging in suitable micro-habitats in search of burrowing species (Malonza *et al.*, 2011).

ii. *Night searches:* This involved actively searching species in wetlands especially amphibians in their breeding sites. Calling male frogs were followed and captured, or photographed and recorded.

iii. *Oral interviews:* This entailed interviewing community members residing adjacent to the forest. The community members were asked to characteristically describe the kind of herpetofauna they know especially the conspicuous snakes or lizards. They were also asked to describe color, behavior and micro-habits of the herpetofauna. This facilitated getting data for those species that were not encountered during the sampling period.

iv. *Pitfall traps associated with drift fence*: X-shaped drift fence with pitfall traps, consisting of segments of 5 m length were used (Malonza *et al.,* 2011). This is a modification of the array design used by Corn (1994). The drift fence (30 cm high) was stapled vertically onto wooden stakes or pegs. The pitfall traps consisted of 10 litter plastic buckets flush with the ground; in total, every trap array had five buckets. One trap set was set-up in each site and left for at least five nights. Traps were used for detection of small nocturnal crawling herpetofauna not easily detected through other methods. The traps were checked every day.

Collected animals were euthanized in a humane manner according to the standard protocol as outlined by Karns (1986). Amphibian specimens were euthanized with MS222 and reptiles with pentobarbital solution and then preserved in 10% formalin. Tissue samples for later molecular analysis were taken from representative specimens and stored in absolute ethanol. Color photographs of selected species and their habitats were taken and deposited at NMK, Herpetology Section. Voucher material collected has been deposited in the Herpetology Section reference collection section. The species were then identified using published taxonomic keys for reptiles and amphibians (Spawls *et al.*, 2002; Channing and Howell, 2006; Frost *et al.*, 2006; Frost, 2010).

6.2 Habitat alteration and disturbance

Species richness and diversity is directly linked to the quality of the habitat. Human habitat disturbance were qualitatively assessed as these have influence on species distribution, abundance and composition. Assessed types of disturbance included livestock grazing, timber extraction, poles cutting and grass cutting.

6.3 Species richness and diversity analyses

The observed species richness was estimated using the EstimateS 8.2 program (Colwell, 2009) by drawing comparison between Jackknife 1 species richness estimator and the observed species richness. Species accumulation curves were calculated and generated using the software programme EstimateS version 8.2 using 1000 randomizations. Species richness was plotted as a function of the accumulated number of samples (time-limited-searches). The herpetofaunal species diversity was measured with Shannon diversity index.

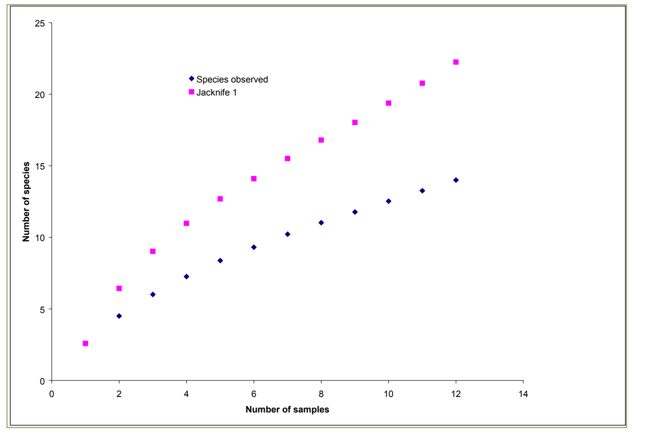
6.4 Statistical data Analysis

One way Analysis of Variance (ANOVA) was used to compare the means of observed total number of individuals, observed species richness and species diversity among the sampling sites per sampling effort (TLS). Data was analyzed with STATISTICA software with significance levels set at 5%.

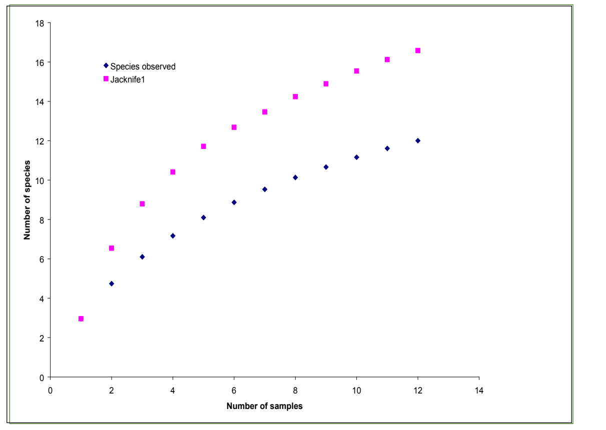
6.5 Results and Discussion

In total, 194 individuals comprising of 25 species of amphibians (3 species of frogs) and 24 reptiles species (3 snakes, 1 tortoise, 20 lizards) were recorded. The present results reflects few species for ASF as compared to other similar forest sites like Kitobo forest (Malonza *et al.,* 2011); Tana River Primate National Reserve (Malonza *et al.,* 2006). This is in contrast with findings of previous studies that have shown that there are more species in ASF than these sites (Drewes, 1992; Chira, 1993). This could be attributed to the very short period of sampling. In terms of composition, amphibians were the most dominant community of herpetofauna in the wetlands visited with East African Puddle frog (*Phrynobatrachus acridoides*) being the most dominant at 29.4%; followed by Savanna Ridged Frog (*Ptychadena anchietae*) at 14.7%. The most dominant reptile was Speke's Sand Lizard (*Heliobolus spekii*) followed by White-headed dwarf gecko (*Lygodactylus mombasicus*) (Table 6.1). Amphibians were mostly recorded in one of the ponds while reptiles were more common in the forest interior and forest edges.

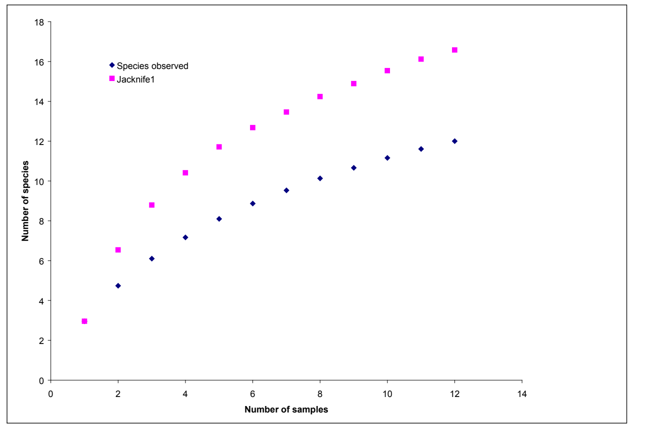
The terrestrial Long-tailed Sand Lizard (*Latastia longicaudata*) and Speke's sand lizard (*Heliobolus spekii)* were the most abundant lizards on the soil surface while the Flat-headed tree gecko (*Hemidactylus platycephalus*) and Tropical house gecko (*Hemidactylus mabouia*) were the most abundant species on the trees. In terms of species richness, the species accumulation curves did not plateau in all the three vegetation types (Figure 6.1). The Jacknife1 species richness estimator for Cynometra woodland was 22 species, Brachystegia forest, 13 species, and Mixed forest, 17 species.



i) Cynometra Forest



ii) Brachystegia Forest



iii) Mixed Forest

Figure 6.1: Species accumulation curves of time-limited search samples in Arabuko Sokoke Forest

Table 6.1: Percentage occurrence of herpetofauna in Arabuko Sokoke Forest

Scientific Name	Common name	Count	Occurrence (%)
Ptychadena anchietae	Savanna Ridged frog	8	0.020997375
Phrynobatrachus acridoides	East African Puddle frog	39	0.102362205
Broadleysaurus major	Great plated lizard	1	0.002624672
Atractaspis microlepidota	Small scaled burrowing asp	1	0.002624672
Boaedon capensis	Cape Brown house snake	2	0.005249344
Agama lionotus	Red headed rock agama	6	0.015748031
Hemidactylus platycephalus	Tree gecko	32	0.083989501
Hemidactylus mrimaensis	Kaya Mrima tree gecko	6	0.015748031
Trachylepis planifrons	Tree skink	3	0.007874016
Trachylepis striata	Striped skink	6	0.015748031
Lygodactylus mombasicus	White-headed dwarf gecko	13	0.034120735
Hemidactylus mabouia	Tropical house gecko	9	0.023622047
Trachylepis brevicollis	Short necked skink	1	0.002624672
Naja melanoleuca	Forest cobra	1	0.002624672
Varanus albigularis	White throated savanna monitor	1	0.002624672
Chamaeleo dilepis	Flap necked chameleon	2	0.005249344
Latistia longicaudata	Southern long tailed lizard	7	0.018372703
Heliobolus spekii	Speke's sand lizard	39	0.102362205
Trachylepis maculilabris	Speckle lipped skink	13	0.034120735
Stigmocheyks pardalis	Leopard tortoise	1	0.002624672
Hemidactylus brooki	Brook's gecko	1	0.012624672
Cordylus tropidosternum	Tropical girdled lizard	2	0.005249344
Psammophis punctulatus	Speckled sand snake	3	0.007874016
Gastropholis prasina	Green keel bellied lizard	1	0.002624672
Bitis arietans	Puff adder	1	0.002624672

Species diversity as estimated by Shannon diversity index was higher in Cynometra (2.32) followed by Brachystegia (2.14). Mixed forest had the least diversity (1.91). The mean species richness per sampling effort (TLS) was highly significant (p=0.00068) among the sites. Similarly species diversity was significantly different (p=0.012) among the three sites.

6.6 Conclusion

Species richness and diversity were highest in Cynometra woodland and lowest in Brachystegia forest. This means that Cynometra vegetation has more habitat niches to support more herpetofauna species. However, Cynometra vegetation type is exploited largely for local wood supplies and this reduces the micro-habitats for various reptiles and amphibians.

6.7 Recommendations

1. Given that the species accumulation curves did not plateau, it means more species can be recorded with additional long term sampling. Long term sampling is therefore recommended to capture additional data on herpetofauna.

2. The Cynometra forest support the highest number of herpetofauna species. Protection of this forest type should therefore be emphasized. Given that Cynometra vegetation type is protected under the now nature reserve, its protection should be enhanced and expanded to include the remaining Cynometra vegetation.

3. Reptiles and amphibians in ASF are highly threatened due to their limited dispersal capability. Efforts should be made to protect their habitats to avoid local population declines and/or disappearances.

4. The high human habitat disturbance levels in Brachystegia forest and Mixed forest need to be checked if habitat restoration for species recovery and maintenance is to be realized.

5. A long term study for Arabuko-Sokoke Forest is recommended to get a better understanding of its herpetofauna.

Lygodactylus mombasicus

Trachylepis maculilabris

Ptychadena anchietae

Bitis arietans

Phrynobatrachus acridoides

Naja melanoleuca

Figure 6.2: Herpetofauna species recoded in Arabuko Sokoke Forest

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CHAPTER 7: UTILIZATION AND GOVERNANCE OF ARABUKO SOKOKE FOREST

L. Ndalilo, M.T.E. Mbuvi and A.M. Luvanda

7.0 Introduction

Arabuko Sokoke Forest (ASF) is one of the 35 global biodiversity hotspots (Marchese, 2015) that attract local, national and international attention and support. The forest was gazetted as a forest reserve in 1943, but has continued to suffer from unsustainable exploitation. Population growth, coupled with increasing demands for timber and agricultural land have contributed to deteriorating condition of the forest (ASFMT, 2002; Mbuvi *et al.,* 2007 and Otieno *et al.*, 2013). Most of the trees of commercial value have been illegally exploited. The adjacent communities continue to depend on the forest for subsistence use. Poor enforcement of the law coupled with illegal exploitation has contributed to forest degradation and loss of biodiversity (ASFMT, 2002). Formal exploitation through Community Forest Association (CFA) participation is progressively degrading the forest as CFAs make KES 1,140,000 per year through KES 20 levy per head-load of firewood sold to communities. This translates to 5,700 metric tonnes of firewood exploited from the forest annually (Per. Comm. Mr. Abbas Chairman Arabuko Sokoke forest Adjacent Dweller Association -ASFADA). These levels of exploitation are un-sustainable.

The Arabuko Sokoke Strategic Forest Management Plan (2002 - 2027) aims at mitigating challenges and threats faced by Arabuko Sokoke Forest ecosystem. Furthermore, it contributes towards: restoration of degraded areas; conservation of rare birds and mammals; sustainable utilization of the natural resources available in the forest and active participation of forest adjacent communities in its management (Mbuvi and Ayiemba, 2005). This plan has been elaborated through Participatory Forest Management Plans which have been done for each of the three ASF forest stations of Sokoke, Jilore and Gede. To date, ASF remains degraded with much of the degradation attributed to anthropogenic factors. This study assessed the socio-economic characteristics of communities living adjacent to ASF and their impact on forest utilization and management for the last 100 years.

7.1 Study methodology

Data was collected through interviews with forest adjacent individuals and key informants using semi-structured questionnaires and checklists respectively. Snow ball sampling technique was adopted to identify 50 forest adjacent households who have lived and interacted with the forest for at least 30 years. The interviews targeted households living within a distance of 5 km from the forest. A total of 18 key informants comprising knowledgeable community members, current and retired government officials and NGO representatives were interviewed. The feedback was done to countercheck and validate any information that was not clear. Data was collected on forest use, utilization, anthropogenic factors and forest governance issues.

7.2 Results and discussion

7.2.1 Demographic characteristics of respondents

The age, gender and education levels of respondents directly influence resource utilization trends and anthropogenic effects on the forest hence these factors were assessed.

7.2.1.1 Age of respondents

Majority of respondents were aged 66 years and above with the youngest respondents ranging between 36-45 years (Figure 7.1). This study targeted older forest adjacent dwellers that had adequate interaction with the forest and its management. Collectively, those in 36 to 65 years comprised 53% of the respondents as compared to 47% in 66 years and above age group. Economically active age group has a strong bearing on forest utilization and conservation.

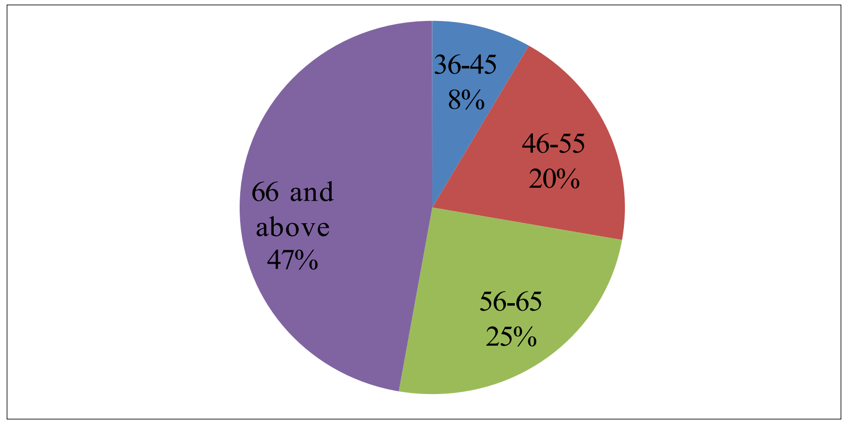

Figure 7.1: Age of respondents

7.2.1.2 Gender of respondents

Majority of the respondents (83%) were male. Gender has a bearing on forest resource utilization with males mainly participating in formulation of by-laws while women are involved in utilization.

7.2.1.3 Education levels of the respondents

Level of education is important for overall development of individuals and society at large. The study revealed that 66% of respondents had no formal education while 22% had attained primary level of education. Only 14% had secondary school education. The education levels of forest adjacent communities was generally lower than those in Kilifi County which stood at 52% for primary level education, 13% for secondary level, while 36% had no formal education (KNBS and SID, 2013). Education was a proxy variable for livelihood improvement through employment creation thus playing a key role in poverty reduction. Poverty has a direct relationship with the level of dependence on natural resource; people with lower education level tend to rely more on natural resources for their survival (Chambers and Conway, 1991).

7.2.2 Socio-economic characteristics of the community

7.2.2.1 Economic activities

Farming was the main source of livelihood for communities living adjacent to Arabuko Sokoke Forest (77%) as reported by Mbuvi *et al.,* (2007). Other economic activities include; business (10%), casual labour (10%) and salaried employment (3%) as presented in Figure 7.2. According to Matiku *et al.*, (2013) forest-adjacent communities are subsistence farmers who utilize the forest for their livelihood. Food crops grown by these farmers include maize, cassava and cowpeas while cash crops include coconut, mango and cashew-nut. This implies that in the last ten years ASF adjacent communities economic activities have hardly changed.

Other sources of income were; tree farming, charcoal production, livestock production, firewood collection, bee keeping and butterfly farming. Local communities are increasingly taking up casual labour and small scale businesses to supplement household income. These findings differ from what was reported by Matiku *et al.*, (2013) and Mbuvi *et al.*, (2007) that informal forest access was the main source of income. This shift in household economic activities could be attributed to increased

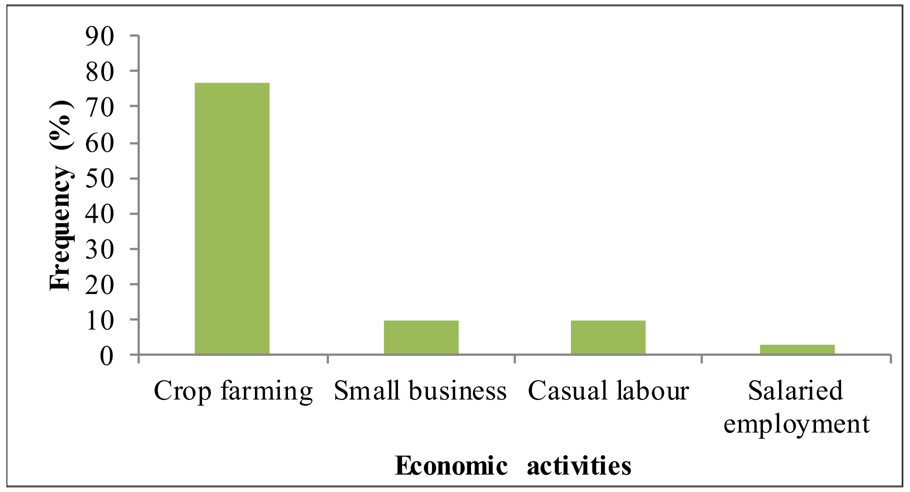

Figure 7.2: Main economic activities

awareness, and low demand for forest products attributed to poor performance of the local economy. According to FGD respondents, tourism was perceived to be the main economic activity in the past but the global economic crisis coupled with cases of insecurity has led to remarkable decline in tourism activities leading to loss of employment and revenue between 2013 and 2015. Tree farming was fairly ranked as a contributor to income. This is an indicator that local communities are increasingly taking up tree farming. This was attributed to enhanced conservation activities through donor funded projects such as introduction of participatory forest management. The trees are mainly grown for commercial purposes.

According to key informants, considerable gains for conservation and local livelihoods have been made over the last twenty years through a number of donor funded projects coordinated by Birdlife International, Nature Kenya and ASFADA. These include improved governance through: pioneering Participatory Forest Management; formation of an Arabuko Sokoke Forest Management Team (ASFMT) comprising various Government departments and NGOs; establishment of Arabuko Sokoke Forest Adjacent Dwellers Association (ASFADA), and the development of a 25-year Strategic Forest Management Plan in 2002. Furthermore, diverse income generating activities initiated through donor funded projects in Arabuko Sokoke Forest have reduced vulnerability of local people leading to their acknowledgement of the value and importance of the forest.

Trade in charcoal contributes to income though considered an illegal forest based activity as only firewood for domestic use is permitted in ASF. Results indicate that despite efforts to improve forest management and conservation, illegal forest exploitation activities continue to negatively impact on conservation. According to Matiku *et al.* (2013), 30% of residents use ASF for charcoal production with many unemployed youths practicing charcoal production as a means of improving their livelihoods. He further argues that absolute poverty results in heavy domestic demands, especially for firewood, building materials, and illegal activities such as poaching of animals and harvesting of poles which are sold in the surrounding urban areas such as Malindi, Kilifi and Mombasa. Such activities endanger forest resources which support local communities leading to a vicious cycle of forest degradation and poverty.

7.2.2.2 Forest dependent economic activities

Firewood collection (40%), was a dominant forest-based economic activity. The other important activities included extraction of construction materials (24%) and charcoal production (17%). Bee keeping and farming at 10% and 9% respectively were also practised (Figure 7.3).

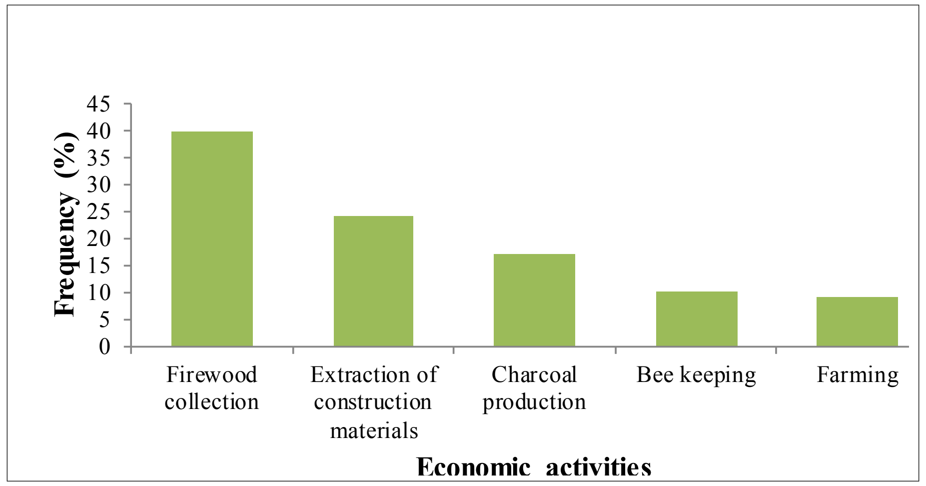

Figure 7.3: Household forest based economic activities

Firewood was the main source of fuel amongst forest adjacent communities while bee keeping was initiated as a sustainable economic activity through Participatory Forest Management (PFM) system. Construction materials such as poles and *fitos* were poached from the forest. These activities negatively impacts through reduction in forest cover. Analysis of changes in income generated from forest based livelihood activities over the years indicated that income declined from 1980s to 2015. This could perhaps be attributed to a decline in quantities extracted from the forest as a result of enforcement of rules and regulations restricting access to forest resources, or supressed demand for forest products due to poor performance of local economy. This was attributed to a shift from mud houses to brick houses which are more permanent. For instance, income generated from construction materials (the highest income earner), declined from Ksh. 450,000 in 1980s to Ksh. 150,000 per annum in 2015 (Figure 7.4).

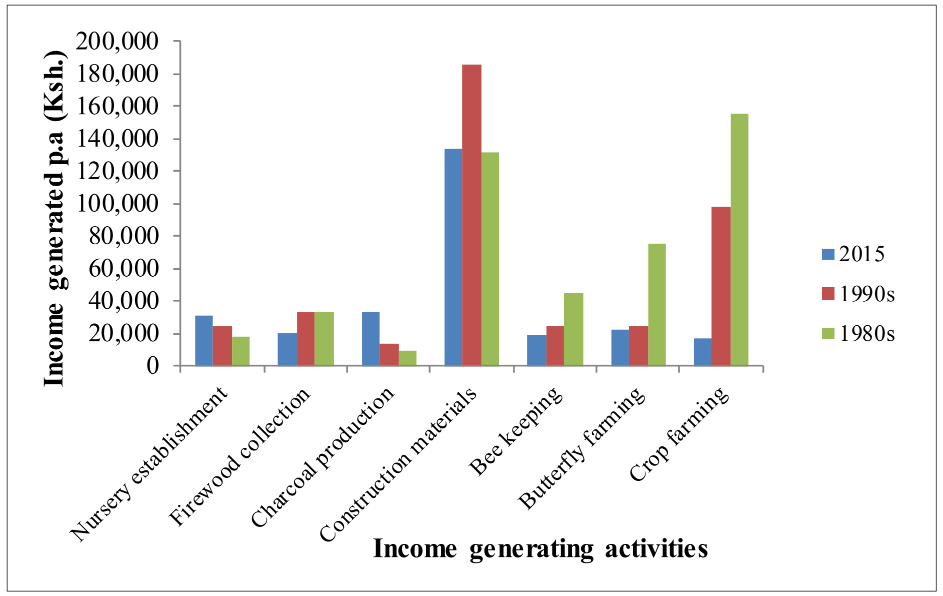

Figure 7.4: Income from forest based IGAs

7.2.3 Forest utilization trends

Firewood collection was the main forest use while wild fruits collection featured last (Figure 7.5).

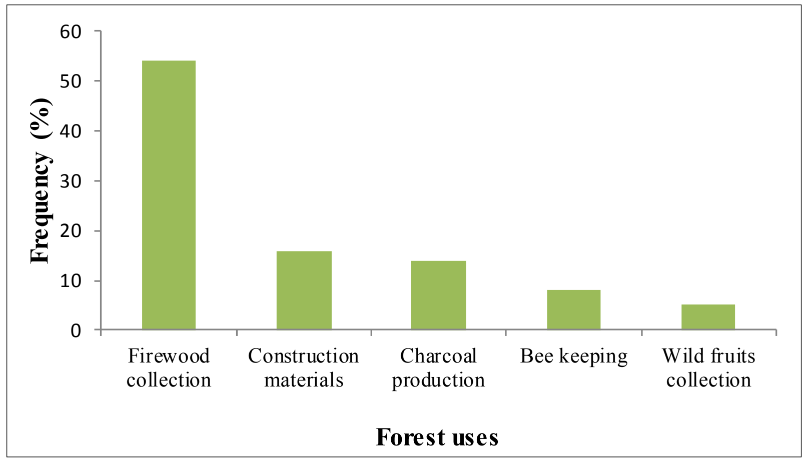

Figure 7.5: Main household forest uses in Arabuko Sokoke Forest

Analysis of forest utilization patterns revealed that forest utilization declined from 1980s to 2015 (Figure 7.6).

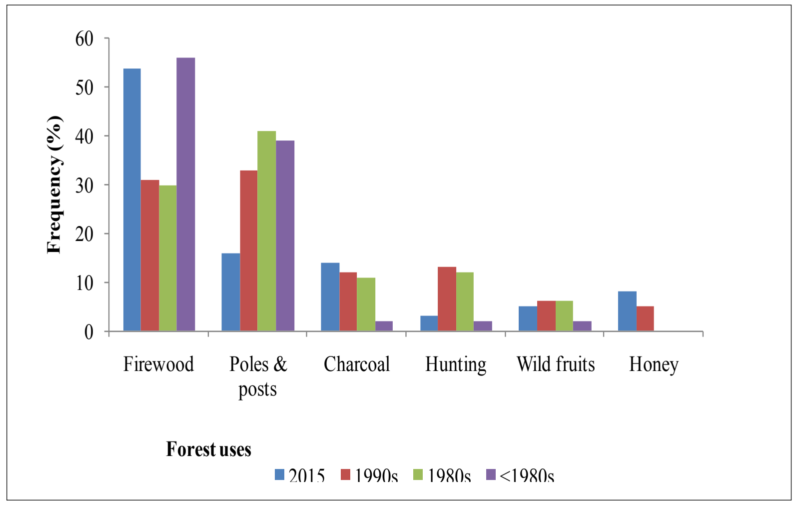

Figure 7.6: Trends in utilization of Forest

According to respondents, the period between 1960s and 1970s witnessed high timber harvesting by licensed saw millers and illegal loggers especially in Matsangoni, Kararacha and Mwambani areas. This period was characterized by over-exploitation of *Brachylaena huillensis* for wood carving. In the late 1970s and early 1980s, licensed cutting of construction poles for hotel construction and/or renovation for the peak tourism season was the most common forest resource use. During this period, cultivation of food crops in the forest under the Plantation Establishment and Livelihood Improvement Scheme was also practiced by forest adjacent communities.

Utilization of ASF was controlled between mid-1980s and late 1990s mainly due to rigorous forest patrols and stakeholder collaboration in forest management witnessed during the KIFCON and Birdlife international projects. This led to a decline in extraction of resource from the forest. Year 2000 to date has been characterized by Mixed forest utilization trends. The Forest Act, 2005 legalized access to licensed fuelwood extraction with PFM providing more forest access opportunities through Community Forest Associations. The restricted access to forest resources coupled with the general feeling that communities are not fairly compensated for their efforts in conservation, has resulted to reported cases of poaching of forest products (Figure 7.7) for both subsistence and commercial purposes thus indicating a possible existence of market for forest products.

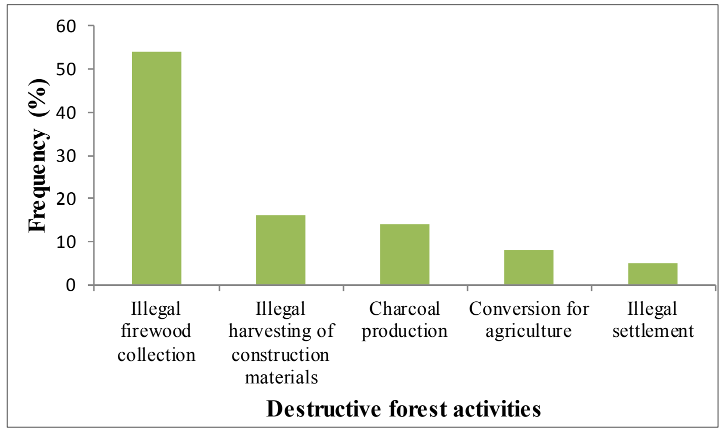

Figure 7.7: Destructive forest activities in Arabuko Sokoke Forest

Findings indicate that illegal firewood collection, harvesting of construction materials, charcoal production, conversion for agriculture, and illegal settlement continues in the forest. Majority of respondents said that destructive activities had contributed to decrease in forest cover, climate change and reduced rainfall (Figure 7.8).

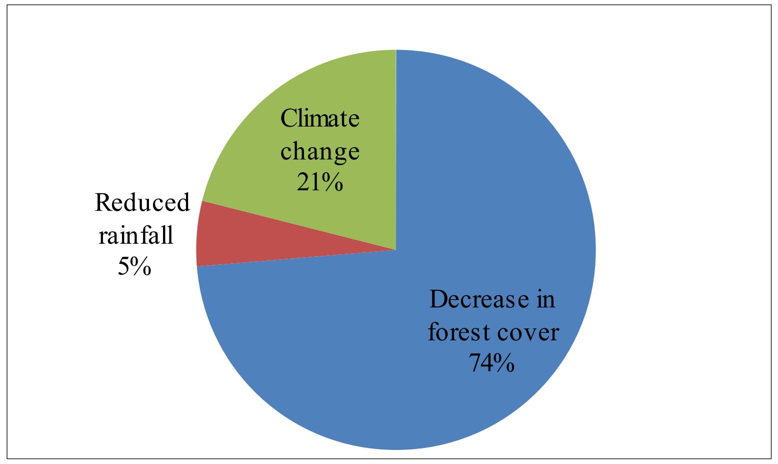

Figure 7.8: Effects of illegal extraction on forest condition

Over time, population growth, coupled with increasing demands for timber and land for agriculture, have contributed to a reduction in the condition of forest. Decline in number of tourists from early 2000s to 2015 has left residents without alternative income sources. Most of the local communities have turned to illegal activities in the forest for survival.

7.2.4 Trends in forest management and implication on forest conservation

Forest management and conservation has continuously changed with time. Focused Group Discussion and key informant interviews indicated that protection and conservation of ASF has not been fully achieved. This was attributed to anthropogenic impacts on the forest coupled with inadequate forest governance. The conservation of ASF was achieved between 1943 and early 1960s, this trend was reversed from late 1960s to early 1970s as a result of licensed sawmills targeting *Afzelia quanzensis*. Moreover, harvesting of *Brachylaena huillensis* for export was still on-going. Over-exploitation (both licensed and unlicensed) of poles and timber resulted in poor forest conservation. The tourism boom of the late 1970s and early 1980s resulted in increased demand for construction poles obtained through poaching (Table 7.1). The situation was further exacerbated by inadequate financial and human resources for forest management.

Table 7.1: Trends in Forest management and its implication on conservation

Period	Key events	Management implication
Late 1960s to Early 1970s	Licensed saw millers targeted *Afzelia quanzensis* Licensed harvesting of *Brachylaena huillensis* for wood carving/ export Despite the exploitation, there were still adequate forest resources	Forest fairly conserved
Late 1970s to Early 1980s	Tourism boom resulting in increased demand for construction poles	Forest poorly conserved
Mid 1980s to Mid 1990s	Multi-stakeholder involvement in forest management Donor funded projects Introduction of alternative IGAs High profile of ASF at local and international level	Forest well conserved
Late 1990s to late 2005	Introduction of PFM Enactment of forest legislations e.g Forest Act 2005 Donor funded projects Initiation of alternative IGAs	Forest well conserved
2006 to date	Dilution of role of ASFMT due to institutional interests and lack of transparency High levels of poverty	Forest poorly conserved

From mid 1980s to 2000, forest was well managed through stakeholder involvement leading to improved profile of the forest at local, national and international levels. Several agencies such as Forest Department (FD) (now Kenya Forest Service), Kenya Wildlife Service (KWS), Kenya Forestry Research Institute (KEFRI), National Museums of Kenya (NMK), Nature Kenya and A Rocha Kenya actively participated in forest management. Efforts by diverse stakeholders targeting specific conservation and livelihood initiatives led to better conservation of ASF. Through introduction of various livelihood activities, local communities had incentive to participate in forest management. Joint patrols played an important role in deterring forest destructive activities.

The enactment of the Forest Act, 2005 resulted in transformation of the Forest Department to Kenya Forest Service, and legalization of community involvement in management of the forest. The concept of PFM has not been fully implemented and in the absence of equitable sharing mechanisms for forest based benefits, communities continue to engage in illegal forest activities.

Following introduction of PFM, 81% of the households are involved in forest conservation activities mainly through: reforestation, reporting offenders, undertaking farm forestry to relieve pressure from the forest, and undertaking forest patrols (Figure 7.9).

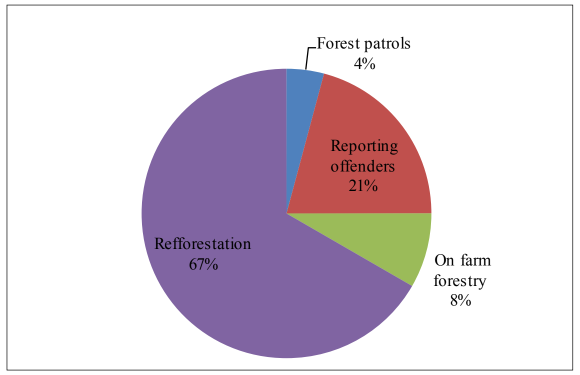

Figure 7.9: Ways of enhancing community involvement in forest conservation

Involvement of the community in forest conservation can be enhanced through continuous sensitization of stakeholders on importance of forest conservation and initiation of alternative income generating activities such as non-forest based activities.

7.2.4.1 Forest Management Approaches

Forest adjacent communities had diverse views on forest management approaches that have been used in Arabuko Sokoke Forest. Majority of respondents were happy with collaborative approach involving multiple stakeholders. Forest management by KFS scored the least (Figure 7.10). The best management option was through partnerships (81%).

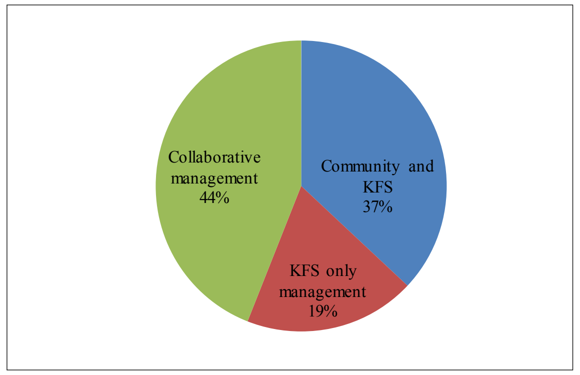

Figure 7.10: Respondents perceptions on forest management approach

Forest Management through KFS was the least preferred approach since the community was aware that the forest is being managed through a partnership with several other organizations. Day-to-day activities were perceived to be coordinated through Arabuko Sokoke Forest Management Team (ASFMT) comprising of membership from the different agencies. Key informants noted that although forest management is the legal mandate of KFS, the involvement of many stakeholders has resulted in better forest management through enhancement of conservation awareness and alternative income generating activities.

7.2.4.2 The role of donor funding in forest management

Focused group discussions and key informant interviews revealed that although multi-stakeholder involvement in forest management coordinated by ASFMT, and supported through donor funded projects had proved to be effective in contributing to better forest conservation, the initiative has been on the reverse trend over time. Since its formation in 1991, ASFMT has been undertaking joint planning and implementation of activities relating to the management and conservation of the forest. Lately, the role of ASFMT has been weakened by lack of transparency and accountability amongst partners; diverse organizational interests have resulted into uncoordinated implementation of activities that do not necessarily address the needs of the forest and stakeholders. The absence of an effective central coordinating unit has resulted to poor forest management and minimal contribution to both forest conservation and local community livelihoods improvement through sustained donor funding totaling to over US$ 536 million to date (Mbuvi and Ayiemba, 2005). A trend Analysis of jointly implemented projects in ASF from 1990 to date is provided in Table 7.2.

Table 7.2: Trend Analysis of jointly implemented projects in ASF (1990 - 2017)

Kenya Indigenous Forest Conservation Project (KIFCON)[1] (1990 - 1993)

- It demonstrated that there are formal and informal benefits of the forest to the community.
- It demonstrated that informal (illegal) benefits from ASF were higher than the legalized benefits.
- Started the initial attempts for community participation in forest management.
- It facilitated the initiation of the process of KWS participation in joint management of ASF through a Memorandum of Understanding (MOU).
- The biggest challenge was how to legalize, diversify and spread the benefits.

Kipepeo Project[2] (1993 to date)

- It demonstrated that communities could get higher returns from non-timber forest products such as butterflies.
- It demonstrated that the attitude of the community towards forest conservation is directly related to the benefits they draw from it.
- This project started ("opened eyes") the first forest based direct non-consumptive benefits
- By 2000 it started facilitating sale of honey produced by ASF FAC with an equipped marketing centre where honey is processed and packaged
- The project has not received funding since 2006

Promotion of Sustainable Forest Management (PSFM)[3] (1993 -1998)

- Emphasized on sustainable management of natural forests.
- It initiated on-farm forestry.
- Conducted Participatory Rural Appraisal (PRAs) focused to initiating community involvement in forestry management.

Arabuko-Sokoke Forest Management and Conservation Project (ASFMCP)[4] (1997-2001)

- Build capacity of Government officers and community to support forest management paradigm shift
- Initiated Participatory Forest Management (PFM) and integrated rural development
- Expanded existing forestry related Income Generating Activities (IGAs) and initiated new ones like beekeeping, community patrolling
- Further developed the ASFMT and community partnerships and structures.
- Government increased funding towards multiple stakeholder management in ASF

[1] Funded by the Government of Kenya and UK through ODA (the current DFID)
[2] Funded by the UNDP-GEF small grants, Chicago Zoological Society, IUCN Netherlands Committee, Japanese Embassy in Kenya, EU and USAID
[3] Funded by the Government of Kenya and Germany through GTZ
[4] Funded by the Government of Kenya and European Commission

Arabuko-Sokoke Forest Community Conservation Initiatives[5] (2003 - 2005)

- Project developed and implemented equally by Government and Community
- Initiated joint human-wildlife conflict deterrent through construction of electric fence in ASF and did the initial 20 km solar fence.
- Initiated joint community and Government officers cross-site visits
- Consolidated existing IGAs like Eco-Tourism, Butterfly farming and Bee keeping.
- Initiated new IGAs like Mushroom farming.
- Enhanced equity in partnership between ASFMT and FAC

Enhanced sustainability of Arabuko-Sokoke forest through Improved Natural Resources Management by and for Stakeholders[6] (2003-2006)

- Consolidating existing IGAs like Eco-Tourism, Butterfly farming and Bee keeping.
- Facilitating the completion of the PFM piloting, scaling up and starting a monitoring system.
- Building CBOs capacity in organization and advocacy.
- Initiated Aloe vera farming as a new IGA
- Expanded PFM to cover two more sites in ASF

Developing Incentives for Community Participation in Forest Conservation through the use of Commercial Insects in Kenya[7] (2004 - 2008)

- Awareness on Participatory Forest Management.
- Beekeeping and sericulture as Income Generating Activities
- Expanded PFM to cover two more sites in ASF
- Capacity building of communities

People and Sustainable Development: Investing in Education, and Social and Economic Empowerment to conserve globally threatened biodiversity in Arabuko-Sokoke Forest, Kenya[8] (2004 - 2008)

- Improving household livelihood so that children live a better life through better farming methods and use of NTFPs.
- Provision of water
- Beekeeping
- Initiated Farm Forestry Field School for improving farming.

Kenya Coastal Development Project[9] (2010 - 2017)

- Biodiversity assessment in ASF
- Support to community nursery groups
- Establishment of commercial woodlots
- Rehabilitation of degraded forest ecosystems
- Establishment and maintenance of seed sources

[5] Funded by the Government of Kenya and European Commission and the Forest Adjacent Community
[6] Funded by the Government of Kenya and the Government of United States of America
[7] Funded by GEF and Government of Kenya
[8] Funded by Germany Civil society (Kindernothilfe and Naturschdeutchland)
[9] Funded by Government of Kenya through support of the World Bank

Smallholder Innovation for Resilience Project[10] (2012 - 2017)

- Improving the adaptive capacity of Coastal communities against the impacts of climate change
- Sustainable utilization of forest products for Nature based Enterprises development
- Capacity building of community groups in Nature based enterprises
- Preservation of cultural heritage and conservation of agrobiodiversity

Arabuko Sokoke Landscape Project[11] (2012 - 2015)

- Improving household livelihood
- Awareness on PFM
- Capacity building of local communities

Strengthening Community Capacity to adapt to Climate Change[12] (2014 - 2015)

- Planting of drought resilient crops
- Establishment of tree nurseries
- Poultry keeping
- Capacity building of Farm Forestry Field School (FFFS)

Capacity building of Forest Adjacent Communities, Kenya[13] (2015 - 2017)

- Capacity building of local communities
- Enhancing the effectiveness of Community forest associations

7.2.5 Forest governance trends

There was a high level of awareness on existing laws on forest use and management such as issuance of forest permits (97%) and policing (3%). The level of compliance to these laws was however low (Figure 7.11). This is an indication that forest adjacent communities continue to engage in forest destructive activities.

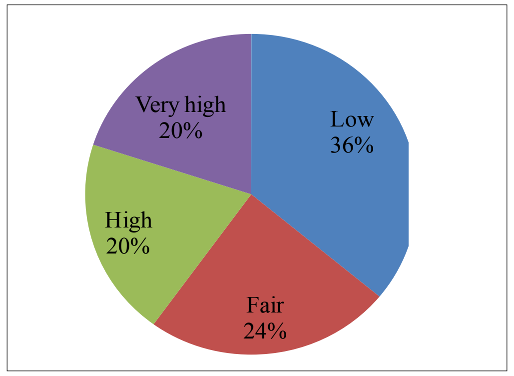

Figure 7.11: Level of community compliance with forest regulations

Respondents cited corruption, inadequate enforcement of laws, poor communication, poverty, inadequate community awareness on laws governing the forest, and deforestation as the main challenges to forest governance (Figure 7.12).

[10] Funded by the European Union through International Institute of Environment and Development (IIED)
[11] Funded by EU through Community Development Trust Fund (CDTF)
[12] Funded by Food and Agriculture Organization of the United Nations (FAO)
[13] Funded by Danish Ornithological Fund (Birdlife Denmark)

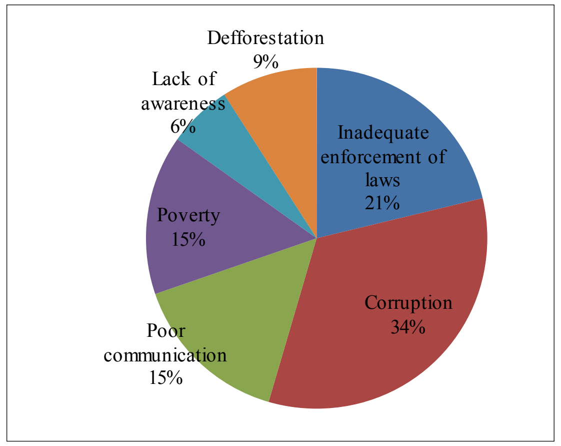

Figure 7.12: Challenges to forest governance

The proposed measures to address these challenges include fines and penalties, adequate community involvement in forest management, and awareness creation on the existing governance system. In addition, alternative income generating activities should be initiated to reduce illegal activities in the forest (Figure 7.13).

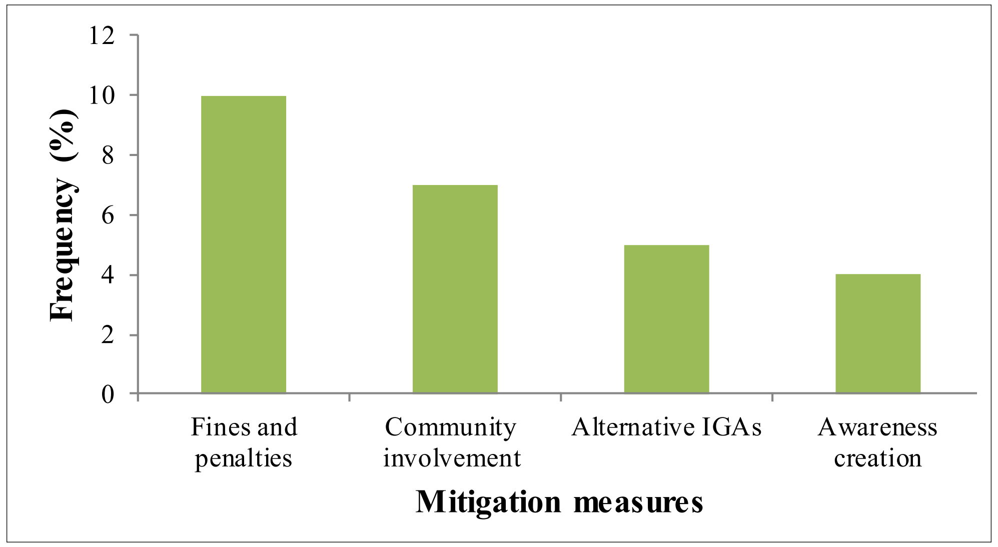

Figure 7.13: Ways of enhancing forest governance

7.3 Conclusion and Recommendations

The main economic activities for the local communities living around Arabuko Sokoke Forest are farming and casual labour. Communities utilize the forest mainly for extraction of firewood and construction materials. Respondents reported local trade in charcoal and firewood as a source of household income. This was an indicator of illegal activities in the forest which have impacted negatively on forest conservation. Quantity of forest products extracted have however been declining except for fuelwood, a situation that was attributed to the low demand for forest products especially poles and posts resulting from poor performance of the local economy, and change in housing structure i.e. from mud houses to brick houses. Information from key informants and forest adjacent households revealed that forest governance system has broken down since colonization era to date. This was attributed to unlawful practices, poverty and lack of incentives for communities to meaningfully participate in forest management. The situation is further complicated by the fact that despite the numerous donor funded projects implemented in Arabuko Sokoke Forest from 1990s to date, the forest condition continues to deteriorate. There is need to understand why ASF continues to be degraded despite the sustained donor funding and multi-stakeholder collaboration.

It is recommended that community sensitization and awareness creation be enhanced, and incentives given to local community for effective participation in forest management. Partner and stakeholder accountability need to be improved where the ASFMT members share work plans and budgets so as to improve on delivery. Alternative income generating activities should be initiated to address the problem of poverty, and good governance through strict enforcement of forest laws and regulations.

This information will be used in monitoring and evaluation of forest use. There is need for a market survey assessing existing wood and non-wood forest products markets which drives forest destruction in ASF. There is also need to undertake a periodic assessment of the impact of forest utilization and governance on community livelihoods so as to guide forest management and devise ways of improving community livelihoods and sustain community and other stakeholder interest to participate in ASF management.

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Appendix I: List of Mammals recorded in either Cynometra forest (2010, 2015) or Brachystegia forest (2015) within in the Arabuko-Sokoke Forest [1]

No	Family	Species	Common name	CT grid presence	IUCN status	Habitat	Habit	Wt. kg (M, F, Avg.)
1	Viverridae	*Civettictis civetta*	African civet	Brachystegia, Cynometra (2015)	LC	M	T	10.9, 11.6, 11.3
2	Viverridae	*Genetta maculate*	Central African large spotted genet	Brachystegia, Cynometra (2010,2015)	LC	FS	T/Ar	1.9, 1.7, 1.8
3	Felidae	*Felis caracal*	Caracal	Brachystegia, Cynometra (2010,2015)	LC	M	T	12.9, 10, 11.5
4	Hyaenidae	*Crocuta crocuta*	Spotted hyena	Brachystegia (2015)	LC	M	T	48.4, 55.6, 52
5	Herpestidae	*Helogale parvula*	Common dwarf mongoose	Brachystegia, Cynometra (2010,2015)	LC	B-G	T	0.269, 0.265, 0.270 Assumed to be *H. parvula* from the IUCN species range map, identification (*H.parvula* or *H. hirtula)* from images was not possible
6	Herpestidae	*Herpestes sanguinea*	Slender mongoose	Cynometra (2015)	LC	M	T	0.637, 0.459, 0.550
7	Herpestidae	*Bdeogale omnivore*	Sokoke bushy-tailed mongoose	Brachystegia, Cynometra (2015)	V	FS	T	1.2
8	Herpestidae	*Ichneumia albicauda*	White tailed mongoose	Brachystegia, Cynometra (2010,2015)	LC	M	T	4.49, 4.14, 4.32
9	Mustelidae	*Mellivora capensis*	Honey badger	Brachystegia, Cynometra (2010,2015)	LC	M	T	11.7, 9.5, 10.6
10	Macroscelidinae	*Petrodromus tetradactylus*	Four-toed sengi	Brachystegia, Cynometra (2010,2015)	LC	FS	T	0.2
11	Rhynchocyoninaeae	*Rhynchocyon chrysopygus*	Golden-rumped sengi	Brachystegia, Cynometra (2010,2015)	EN	FS	T	0.54
12	Cercopithecinae	*Cercopithecus mitis sub species albolgularis*	Zanzibar Sykes' monkey	Brachystegia, Cynometra (2010,2015)	LC	FS	Ar	5.7, 3.6, 4.65

1 **Key:** The species are grouped by trophic categories. The species average adult body mass in kilograms, IUCN status, general behavior (Ar=Arboreal, Aq, Aquatic, T=Terrestrial, U=Unknown) and habitat preference (M=Mixed, B-G=Bush-Grassland, FS=Forest Specialist, SA=Semi-Aquatic, I=Indetermined) are also provided

No	Family	Species	Common name	CT grid presence	IUCN status	Habitat	Habit	Wt. kg (M, F, Avg.)
13	Cercopithecidae	*Papio cynocephalus*	Yellow baboon	Brachystegia, Cynometra (2015)	LC	B-G	T	24.9, 13.6, 19.25
14	Galagidae	-	Galago *spp.*	Brachystegia, Cynometra (2010, 2015)	LC	I	Ar	At least four galago species potentially present.
15	Leporidae	*Lepus capensis*	Cape hare	Brachystegia (2015)	LC	M	T	2.25
16	Nesomyidae	*Cricetomys gambianus*	Gambian giant rat	Brachystegia, Cynometra (2010, 2015)	LC	M	T/Ar	0.79
17	Muridae	-	Murid sp.	Brachystegia, Cynometra (2015)	N/A	I	T	-
18			1 squirrel sp.	Brachystegia (2015)	N/A	I	U	0.2
19	Sciuridae	*Paraxerus palliatus*	Red bush squirrel	Brachystegia, Cynometra (2010,2015)	LC	M	T/Ar	0.38 (average)
20	Hystricidae	*Hystrix cristata*	Crested porcupine	Brachystegia (2015), Cynometra (2010)	LC	M	T	20
21	Bovidae	*Cephalophus adersi*	Aders' duiker	Cynometra (2010, 2015)	CR	FS	T	9.2, 9, 9.10
22	Bovidae	*Cephalophus monticola*	Blue duiker	Brachystegia, Cynometra (2010, 2015)	LC	FS	T	4.8, 5.3, 5.05
23	Bovidae	*Sylvicapra grimmia*	Common duiker	Brachystegia (2015)	LC	B-G	T	18.5
24	Bovidae	*Cephalophus harveyi*	Harvey's duiker	Brachystegia, Cynometra (2010, 2015)	LC	FS	T	11.3, 11.9, 11.60
25	Bovidae	*Neotragus moschatus*	Suni	Brachystegia, Cynometra (2010, 2015)	LC	FS	T	5, 5.4, 5.20
26	Bovidae	*Tragelaphus scriptus*	Bushbuck	Brachystegia, Cynometra (2010, 2015)	LC	M	T	42, 28, 35.00
27	Bovidae	*Syncerus caffer*	African buffalo	Brachystegia (2015)	LC	M	T	750.8, 446.6, 598.7
28	Suidae	*Potamochoerus larvatus*	Bushpig	Brachystegia, Cynometra (2010, 2015)	LC	M	T	52, 61, 56.5
29	Elephantidae	*Loxodonta africana*	African elephant	Cynometra (2015)	V	M	T	6048 (max), 3232 (max), 4640
30	Orycteropidae	*Orycteropus afer*	Aard-vark	Brachystegia, Cynometra (2010, 2015)	LC	M	T	53.3, 51.4, 52.35

Appendix II: Mammals of Arabuko Sokoke Forest

Species	Forest type		
	Cynometra 2010	Cynometra 2015	Brachystegia 2015
Mammal			
Aardvark*	X	X	X
Aders' duiker *†	X	X	
African buffalo*			X
Blue duiker *†	X	X	X
African civet*		X	X
African elephant*		X	
Bushbuck*	X	X	X
Bushpig*	X	X	X
Four-toed sengi †	X	X	X
Cape hare*			X
Caracal*	X	X	X
Common dwarf mongoose	X	X	X
Crested porcupine*			X
Central African large-spotted genet *†	X	X	X
Common duiker*			X
Galago sp.	X	X	X
Gambian giant rat*	X	X	X
Golden-rumped sengi *†	X	X	X
Harvey's duiker *†	X	X	X
Honey badger*	X	X	X
Red bush squirrel	X	X	X
Murid spp.		X	X
Suni *†	X	X	X
White-tailed mongoose*	X	X	X
Zanzibar Sykes's monkey*	X	X	X
Sokoke bushy-tailed mongoose *†		X	X
Squirrel spp.			X
Spotted hyena			X
Yellow baboon*		X	X
Slender mongoose*		X	
Bird			
African goshawk		X	
Boubou shrike		X	
Eastern bearded scrub robin		X	X
Eastern Crested Guinea-fowl		X	X
Boubou shrike			X
Fishers green bull		X	
Paradise fly-catcher		X	
Tambourine dove		X	
Marsh owl			X
Mourning collared dove			X
Tambourine dove			X
Reptile			
Skink spp.		X	
Snake spp.		X	
Terrestrial Monitor			X

Appendix III: Point count locations for birds' baseline survey in Arabuko Sokoke Forest

Point ID	Mixed Forest		Brachystegia Woodland		Cynometra Woodland	
	GPS Coordinates	UTM	**GPS Coordinates**	UTM	**GPS Coordinates**	UTM
1	37M 0604769	9633054	37M 0602916	9632988	37M 0597385	9633068
2	37M 0604523	9632955	37M 0602732	9633096	37M 0597050	9633188
3	37M 0604225	9633054	37M 0602500	9633075	37M 0596795	9633083
4	37M 0603921	9632963	37M 0602263	9633215	37M 0596738	9633535
5	37M 0603706	9633031	37M 0602052	9633041	37M 0596971	9633566
6	37M 0603425	9632885	37M 0601895	9633078	37M 0597213	9633539
7	37M 0603271	9632946	37M 0601698	9632973	37M 0597403	9633623
8	37M 0598800	9632838	37M 0601460	9633035	37M 0597698	9633546
9	37M 0603418	9633535	37M 0601233	9632955	37M 0597926	9633591
10	37M 0603681	9633531	37M 0600810	9633124	37M 0598095	9633469
11	37M 0603836	9633626	37M 0600258	9633141	37M 0598704	9633555
12	37M 0604039	9633471	37M 0602180	9633623	37M 0598978	9633555
13	37M 0604160	9633587	37M 0602357	9633482	37M 0599252	9633554
14	37M 0604438	9633513	37M 0600623	9633553	37M 0599527	9633554
15	37M 0600075	9633554	37M 0601987	9633507	37M 0599801	9633554
16	37M 0600349		37M 0602618	9633625	37M 0598656	9633016
17	37M 0600090	9632987	37M 0602700	9633355	37M 0598442	9633044
18	37M 0604190	9634096	37M 0602983	9633531	37M 0597735	9633025
19	37M 0603916	9634096	37M 0603194	9633592	37M 0597877	9633009
20	37M 0603641	9634096	37M 0600942	9633028	37M 0599801	9633089
21	37M 0603367	9634096	37M 0602818	9634096	37M 0599321	9632911
22	37M 0603093	9634096	37M 0602544	9634097	37M 0599073	9632696
23	37M 0602818	9634096	37M 0602544	9634097	-	-

Appendix IV: A list of birds recorded during the baseline survey at Arabuko Sokoke

	Common Name	Scientific Name	Site Recorded		
			1	2	3
1	Retz's Helmetshrike	*Prionops retzii*	√		
2	Slate-collard boubou	*Laniarius funebris*		√	
3	Black backed puffback	*Dryoscopus cubla*	√	√	
4	Chestnut-fronted Helmetshrike	*Prionops scopifrons*	√		√
5	Tropical boubou	*Laniarius aethopicus*	√	√	√
6	Amani Sunbird	*Hedydipna pallidigaster*	√		√
7	Collared Sunbird	*Hedydipna collaris*	√	√	√
8	Olive sunbird	*Cyanomitra olivacea*	√	√	√
9	Purple-banded sunbird	*Cinnyris bifasciatus*			√
10	East bearded scrub robin	*Cercotrichas quadrivirgata*	√	√	√
11	East Coast Akalat	*Sheppardia gunningi*			√
12	Pale flycatcher	*Bradornis pallidus*	√		
13	Ashy flycatcher	*Muscicapa caerulescens*	√		
14	Little yellow flycatcher	*Erythrocercus holochlorus*	√		√
15	Black headed apalis	*Apalis melanocephala*	√	√	√
16	Grey Backed Camaroptera	*Camaroptera brachyura*	√	√	√
17	Tiny Greenbul	*Phyllastrephus debilis*	√	√	√
18	Yellow Bellied Greenbul	*Chlorocichla flaviventris*	√	√	√
19	Zanzibar Sombre Greenbul	*Andropadus importunus*	√	√	
20	Eastern nicator	*Nicator gularis*	√		
21	Fischer's greenbul	*Phyllastrephus fischeri*		√	√
22	Speckle-Breasted wood pecker	*Dendropicos poecilolaemus*		√	
23	Mombasa Woodpecker	*Campethera mombassica*	√	√	√
24	Black headed oriole	*Oriolus larvatus*	√		√
25	Eurasian golden oriole	*Oriolus oriolus*	√		
26	Red-tailed Ant thrush	*Neocossyphus rufus*	√		√
27	Commom drongo	*Dicrurus adsimilis*		√	
28	Dark backed weaver	*Ploceus bicolor*	√		√
29	Fiery-necked nightjar	*Caprimulgus pectoralis*	√		
30	Common Scimitarbil	*Rhinopomastus cyanomelas*	√		
31	Forest batis	*Batis mixta*	√	√	√
32	Green barbet	*Stactolaema olivacea*			√
33	Little sparrowhawk	*Accipiter minullus*	√		
34	Pale batis	*Batis soror*	√		√

Key: 1. Brachystegia, 2. Cynometra 3. Mixed forest

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