BIRD SPECIES RICHNESS IN THREE FRAGMENTED COASTAL FORESTS, KWALE DISTRICT-KENYA

SIMON NGANDA MUSILA (B.Sc. Wildlife Management)
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DECLARATIONS

DECLARATION BY THE CANDIDATE

This thesis is my original work and has not been presented or submitted for my degree in any university or for any other award.

..... 10th MAY 2010

SIMON NGANDA MUSILA **DATE**

REG. No: N50/12591/2005

DECLARATION BY THE SUPERVISORS

We confirm that this research work was carried out by the candidate under our supervision.

..... 10th MAY 2010

PROF. SHYAM MANOHAR **DATE**

DEPARTMENT OF ENVIRONMENTAL SCIENCES

KENYATTA UNIVERSITY

..... 10/5/2010

DR. NELSON MANGO **DATE**

DEPARTMENT OF ENVIRONMENTAL STUDIES AND COMMUNITY DEVELOPMENT

KENYATTA UNIVERSITY

DEDICATION

This thesis is dedicated to all honest people who fought for peace and freedom during the December 2007 disputed poll results in Kenya. It is also dedicated to my wife Elisabeth for her continued support.

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LIST OF ABBREAVIATIONS

AELC	African Education Leaders in Conservation
ANOVA	Analysis of Variance
CBO	Community Based Organization
EACBs	East African Coastal Biome Bird Species
CEPF	Critical Ecosystems Partnership Fund
CFCU	Coastal Forest Conservation Unit
DBH	Diameter at Breast Height
EACF	East African Coastal Forest
GTbs	Globally Threatened Bird Species
IBAs	Important Bird Areas
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
NMK	National Museums of Kenya
RSPB	Royal Society for Protection of Birds
SPSS	Statistical Package for Social Sciences
TSC	Timed Species Count
WWF	World Wildlife Fund

ABSTRACT

This research work was conducted in between October 2007-August 2008 in Kaya Gandini Important Bird Area, Kaya Mtswakara and Mwache Forest Reserve, mainly to investigate bird species richness in the three adjacent coastal forests. Three ringing sites marked 200-500m from each other, each with two net lines (60m (18m x 2, 12m x 2) and (54m (18m x 3) placed at 60m from one another were used to survey understorey birds in each forest. Canopy birds were surveyed using 22 Timed Species Counts (TSCs) in each forest. Vegetation data was collected within $10m^2$ plots marked at intervals of 50m from one another and located at 10m perpendicularly away from the footpaths around the ringing sites and TSCs survey routes. 141 bird species were recorded in all sites, with 93, 88 and 91 species respectively recorded in Gandini, Mtswakara and Mwache. 41 bird species types (29% out of 141) were common in each of the three fragments, which represented 44%, 47% and 45% of all species recorded in Gandini, Mwache and Mtswakara respectively. A total of 38 forest birds were recorded in all forests (17 recorded common/overlapping in all sites), with 34 in Gandini and 25 in both Mtswakara and Mwache. Four globally threatened birds and 14 East African Coastal Biome Bird Species (EACBs) were recorded in all forests. There was no bird species observed dispersed from one forest to another even though the three sites were connected to each other. The habitat structure of three sites was similar even though Gandini and Mtswakara were more similar. Firewood collection, extraction of building poles (5-10cm DBH) for domestic and commercial use in all three forests and quarrying activities in Mwache threatened the survival of birds. Compared to other two forests, Kaya Gandini was the most important site for avifauna conservation because it was richer in Forest Specialist (FF), Forest Generalist (F), under-storey, globally threatened birds and EACBs species. The three forests were very important sites for avifauna conservation, and due to proximity to each and high number of overlapping forest birds and globally threatened bird species, they should be protected or managed as a single forest block, because habitat destruction in one fragment will affect bird species richness in the other neighbouring forests.

Key words: *Forests, birds, fragments, Kayas, species, habitat, biodiversity*

CHAPTER 1: INTRODUCTION

1.1 Background

The coastal forests in Kenya, once a contiguous ecosystem, stretched all the way from Lamu in the North to Lungalunga in the South. These forests exist as small isolated patches of forest in the midst of rapidly increasing human population (Bennun and Njoroge, 1999; Musila, *et al.*, 2005). Human activities such as wood carving, firewood collection, charcoal burning, timber and poles extraction, encroachment for settlement and agriculture and other human development activities remain the main threats (Hamilton, 1981; Howell, 1981; Burgess, *et al.*, 2003). Despite the importance of these forests for biodiversity (with listing of majority of coastal forests and Eastern Arc Mountains in Kenya and Tanzania in the Eastern Arc Mountains and Coastal Forest Biodiversity Hotspot), the deterioration of sites continues as human population grows. Kayas Gandini (150 ha) and Mtswakara (247 ha) and Mwache Forest Reserve (*c.* 345 ha) (Bennun and Njoroge, 1999) are small indigenous forests listed within this hotspot (Burgess *et al.*, 2003). The restoration and increase of connectivity between fragmented forest patches throughout the hotspot based on solid biological knowledge have been proposed as a key Critical Ecosystem Partnership Fund (CEPF) investment strategies and priorities (Burgess *et al.*, 2003). Additionally, there is an urgent need to improve biological knowledge in the biodiversity hotspot because some of them are little known and all of them are highly threatened (Burgess, *et al.*, 2003). Four globally threatened bird species (Sokoke Pipit *Anthus sokokensis*, Plain–backed Sunbird *Anthreptes reichenowi*, Fischer's Turaco *Tauraco fischeri* and Spotted Ground Thrush *Zoothera*

guttata fischeri have been recorded in Kaya Gandini (Bennun and Njoroge, 1999). Previous research in Kaya Mtswakara showed its avifauna to be similar to Kaya Gandini but less diverse and lacking two threatened species (Waiyaki, 1995). No bird surveys have been conducted in Mwache Forest Reserve. Therefore, surveys were required to investigate whether any of the threatened birds occurred in Mwache Forest Reserve, in addition to establishing the status of these species in Kayas Gandini and Mtswakara. This could lead to elevation of the two forest patches as a single Important Bird Area (IBA) together with Kaya Gandini (Bennun and Njoroge, 1999). The additional scientific information on bird community could be used to determine the most effective option of connecting the three forest patches.

1.2 Problem statement and justification

The three forests patches namely: Kaya Gandini, Kaya Mtswakara and Mwache Forest Reserve, were most likely a single continuous forest which was fragmented by expanding human population growth and associated activities. Degradation and modification of the habitats within the forest patches still continue as human settlements, poles extraction, firewood, hunt wildlife and other natural forest resources. Four globally threatened bird species have been recorded in Kaya Gandini (Bennun and Njoroge, 1999), and two species in Kaya Mtswakara. No avian surveys have been done in Kaya Gandini and Mtswakara since the Important Bird Areas (IBA) Directory was produced in 1999. No bird surveys have ever been done in Mwache Forest Reserve (Bennun and Njoroge, 1999). Different coastal forests, even when in close proximity to one another, have been shown to hold surprisingly different groups of flora and fauna (Burgess, *et al.*, 2003). It

was therefore imperative to increase our scientific knowledge on Kaya Mtswakara and Mwache Forest Reserve since currently little was known about them (Burgess *et al.*, 2003; Bennun and Njoroge, 1999). It was likely that they hold some of the East African Coastal Biome species (EACBs). Additionally, human activities probably have had an adverse effect on the populations of birds in these sites, especially the forest specialist species (including globally threatened ones). Given the proximity of the patches to one another there was also the likelihood of inter-fragment dispersal in search of resources such as food, mates and territories.

1.3 Aims and objectives

The overall aim of this project was to investigate avian species richness in the three adjacent forest patches and recommend the most appropriate conservation strategies for bird species and their fragmented habitats.

Specific objectives were to;

1. Investigate the bird species richness in the three fragmented forests.
2. Determine avian dispersal among the three forest fragments.
3. Determine the effects of habitat degradation on avian species richness.
4. Document the status of the threatened and coastal biome bird species
5. Investigate the threats to the three coastal forests.

1.4 Significance and anticipated output

The coastal forests in Kenya are currently under serious threats emanating from human activities. This research will provide information about the conservation status of bird species and their associated habitats. Since birds are relatively good indicators of environmental health (Furness and Greenwood, 1993) the information to be gathered will be used to gauge the levels of threats which exist to other taxonomic groups. The following are the expected results and deliverables of this project: A checklist of bird species in the three forest patches will be produced. The relative abundances of different bird species in the three forests will be known, and will be used to evaluate the most important fragment for the conservation of forest specialists, coastal biome species and the globally threatened birds. The possibilities for increasing connectivity between the forest patches based on the avian data, local community participation and landscape features will be identified. General information on the human activities around the forest patches and how they contribute positively or negatively to long term survival of the three forest patches will be made available for planning of future research and for planners of conservation interventions to save the sites.

1.5 Definition of some biological concepts

Biodiversity Hotspot: an ecosystem with a high concentration of wildlife species.

Bird Ringing: tagging birds with aluminium or plastic rings inserted in one or both legs.

Bird Feeding Guilds: Group of bird not necessary taxonomically related which feed or behave in a similar way (Bennun and Howel, 2002).

Carnivore: Meat eating animal.

Dispersal: Movement of an individual animal from one place to another.

Degradation: Reduction in the quality of an ecological habitat by pollution or extraction of natural resources.

East Africa Coastal Biome Bird Species (EACBs): Bird species endemic to coastal habitats in East Africa (Bennun and Njoroge, 1999).

East Africa Coastal Forest: Forest found along the East African coastal strip from Somalia to Tanzania at most 0-500M above sea level.

Endemic: Species of animal whose distribution is restricted to one site or region.

Forest Specialist (FF): Bird species only found in the interior of undisturbed forest (Bennun and Howell, 2002).

Forest Generalist (F): Bird species common in disturbed forests and rare in the interior of the close-canopy intact forests (Bennun and Howell, 2002).

Forest Visitor (f): Bird species often recorded in the forest, but are not depended upon it (Bennun and Howell, 2002).

Fragmentation: division of a continuous ecological habitat into one or more patches.

Fragment/Patch: A section of continuous ecological habitat separated by a different vegetation type, road, path or other human infrastructure.

Frugivore: Fruit eating bird.

Granivore: Grain eating bird.

Habitat Structure: The gross external appearance of vegetation matter.

Important Bird Areas (IBAs): Are places of international significance for the conservation of birds at the global, regional or sub-regional level (Bennun and Njoroge, 1999).

Insectivore: Insect/small invertebrates feeding animal.

Kaya Forest: A coastal forest used in the past by MijiKendas as hideouts against external attack (Spear, 1978) and currently used as sacred site for conducting cultural ceremonies (Githitho, 1999).

Omnivore: Animal feeding on meat and plants.

Range-restricted Species: species whose total distributional area on earth is at most 50,000 km^2 (Fishpool and Evans, 2001; Stattersfield, *et al.*, 1998).

Species Richness: The number of individual species in a community (Krebs, 1999).

Species Discovery Curve: Number of individual species in a habitat plotted against day, week, month or years.

Timed Species Count: Count of individuals from a fixed point for a given time period.

1.6 Organization of thesis

The chapter that follow reviews literature on coastal forests in Eastern Africa, the biodiversity they contain and the threats they are facing. This also includes the management of these forests in Kenya and bird species found in them, as well as factors which affect distribution of birds in forests habitats. The chapter on study area and methods covers detailed information about the location where the research was carried out and specific methods used to collect data on birds and vegetation as well as data organisation procedures. The results chapter provides outcome of the research by covering bird species richness, different bird species groupings, and dispersal and relative abundances in the study forests. Results about the vegetation structure, management of forests, extraction of forests products by local community and other threats faced by

study areas are also presented. The discussion section which follows immediately after the results synthesises the results in the context of existing research information by comparing what features of the current study agrees or differs with past work. The last chapter on conclusion and recommendation is a distillation of the entire research into situation analysis of birds and their habitats, followed by identification of the specific activities or interventions required to be implemented to protect the sites, birds and other components of biodiversity found in the study areas.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The coastal forests in Eastern Africa comprises of mosaic of forests sites that corresponds to the Wild Wildlife Fund (WWF) eco-region known as the 'Northern Zanzibar-inhambane Coastal Forest Mosaic' stretching from the Somalia to Mozambique (White, 1983). The eco-region is a heterogeneous group of isolated evergreen or semi-evergreen closed-canopy forests, within 60 Km of the Indian Ocean and usually on low hills rising to not more than 600 M above sea level (Burgess and Mulingwa, 1993). In Kenya the coastal forests are confined in a narrow strip except along the Tana River where it extends inland to include the forests of the lower Tana River (within the Tana River Primate Reserve), from the border of Kenya with Somalia to the border with Tanzania (Burgess, *et al.*, 2003). The chains of these forests some very tiny (20 ha), play a very important role in the conservation of biodiversity in Kenya and the whole of Eastern Africa.

2.2 Biodiversity significance of coastal forests in Kenya

A total of 160 coastal forest sites in Kenya and Tanzania are listed in the Eastern Arc Mountains (Taita Hills and Usambara Mountains) and Coastal Forest Biodiversity Hotspot by conservation international and partners. The hotspot stretches from the border of Kenya with Somalia, to the border of Tanzania with Mozambique, including the island of Zanzibar, Mafia and Pemba (Burgess, *et al.*, 2003). The sites in Kenya and Tanzania qualified for listing as a hotspot collectively by virtue of their large number of endemic species and severe degree of threats to species (Burgess, *et al.*, 2003). The main threat is

habitat loss, occurring through opening of coastal forests to provide for the needs of rapidly expanding human population such as farmlands, settlements and construction of infrastructures (beaches, residential houses, roads) Burgess, *et al.*, 2003). Although the hot spot ranks low compared to other hotspots in total numbers of endemic species, it ranks first among the 25 hotspots in the number of endemic plants and vertebrates species per unit area (Myers, *et al.*, 2000). Collectively all the 160 sites harbours at least 1,500 endemic plants, 16 endemic mammals, 22 endemic birds, some 50 endemic reptiles and 33 endemic amphibians (Burgess, *et al.*, 1998a; Lovett and Wasser,1993; Burgess and Clarke, 2000; Myers, *et al.*, 2000). Because of the small area of the hotspot, the densities of these endemics are among the highest in the world (Burgess, *et al.*, 2003).

Burgess, *et al.* (2003) notes that the distribution of endemic species in all sites listed in the hotspot require special consideration. This is because all East Africa Coastal Forest (EACF) patches have high biodiversity values and most of them have at least one endemic species (Burgess and Clarke, 2000) and a high turnover of species between patches, especially in the less mobile species (Burgess, *et al.*, 2003). This is an indication that each forest patch plays a significant role in the conservation of species that are unique to it.

2.3 Threats to coastal forests in Kenya and Tanzania

By the early 1990s, there were about 175 forest patches in the coastal forest mosaic covering an area of 1,360 km^2 (660 km^2 in Kenya and Tanzania 700 km^2): with a mean patch size of 6.7 km^2 in Kenya and 10.6 km^2 in Tanzania (Burgess, *et al.*, 2003). It is

believed that before 1980s the forest were more widespread (Hawthorne, 1993), and probably covered a larger area than today. However, with time much of the forest mosaic has been converted to subsistence agriculture, interrupted by plantations and human settlements including the large towns (Malindi, Watamu, Lamu, Ukunda) and city (Mombasa) Burgess, *et al.*, 2003).

The coastal forests have also faced unsustainable selective poles removal by local communities for construction purposes (traditional houses, erection of tourists infrastructure along the beaches), as well as for timber (Waiyaki, 1995). For instance, Mogaka (1992) estimated that over 30,000 poles were removed annually from Arabuko-Sokoke forest targeting on few selected tree species. He also estimated a removal of 610 tons of fuelwood by local communities from the neighbouring Arabuko-Sokoke Forest. Pole cutting was noted as a major problem at Kaya Waa and Mrima forest by Waiyaki (1995).

The selective removal of trees for the purpose of wood carving has threatened the availability of species such as *Brachylaena huillensis* and *Combretum schumannii*, culminating into virtual local extinction of the species in Kaya Gonja and Mwaluganji (Waiyaki, 1995). The rapidly increasing human population among the coastal communities is probably the biggest threat to the coastal forests. This is because it puts a lot of pressure on the forests through opening of more forests for cultivation, settlements, construction of infrastructure (roads) and extraction of forest products (Ng'weno, *et al.*, 2004; Musila, *et al.*, 2005). The loss of tree species consequently alters the quality and

quantity of suitable habitat available for bird species. The level of habitat loss of a coastal fragment has a negative impact on the density, frequency and distribution of bird species.

2.4 The management of the coastal forests in Kenya

The coastal forests are managed under three main conservation regimes namely; Forest reserve-which can be in/outside a National Park managed by Kenya Forest Department (now Kenya Forest Service (KFS) and Kenya Wildlife Service (KWS); National Monuments-these are sites managed by the National Museums of Kenya under the National Monument Act; and the Kayas-forest fragments managed by sub-tribes of Mijikenda people, since they are believed to be sacred and are of cultural importance (Waiyaki, 1995).

The Kaya is a traditional word for Mijikenda people which mean homestead. The Kaya is a coastal forest representing a fortified village built by the community in a forest to avoid attack by armed tribes from Somali (Spear, 1978). After Kenya's independence in 1963, the fear of invasion among the Mijikenda ceased, and as their population increased they moved out of these forests; but continued to treat the forests as sacred and held their traditional and cultural ceremonies in them (Spear, 1978; Waiyaki, 1995). However, community members continued to extract natural resources from the Kayas; but any unsustainable exploitation of forest resources was controlled by a council of elders through imposition of sanctions on affected tree species (Waiyaki, 1995; Spear, 1978). Modernity and upsurge of civilization has resulted into ignorance of cultural restrictions imposed on the community by council of elders and hence resulted into widespread

exploitation of forest resources in the Kayas (Ng'weno *et al.*, 2004; Musila, *et al.*, 2005; Bennun and Njoroge, 1999).

2.5 Coastal forests bird species in Kenya

The coastal forests of Kenya are rich in bird species. Among these coastal forests, Arabuko-Sokoke Forest is the most important for bird conservation (Fanshawe, 1993). Birdlife International has ranked the forest as the second most important for avifauna conservation in mainland Africa (Collar and Stuart, 1988). More than 230 bird species have been recorded in the forest (Fanshawe, 1993). Nine globally threatened bird species (Fischer'sTuraco (Near-threatened), Sokoke Scops Owl *Otus ireneae* (Endangered), Spotted Ground Thrush (Endangered), Sokoke Pipit (Vulnerable), East Coast Akalat *Sheppardia gunningi sokokensis* (Vulnerable), Amani Sunbird *Anthreptes pallidigaster* (Vulnerable), Plain-backed Sunbird (Near-threatened), Clarke's Weaver *Ploceus golandi* (Vulnerable) and Southern Banded Snake Eagle *Circaetus fasciolatus* (Near-threatened) have been recorded (Bennun and Njoroge, 1999) at Arabuko-Sokoke.

Other coastal forests have fewer numbers of globally threatened species; for example: Dakatcha Woodlands (5), Diani Forest (4), Dzombo Hill Forest (3), Gede Ruins (5), Kaya Gandini (4), Kaya Waa (2), Marenji Forest (3), Mrima Hills (3), Shimba Hills (6), Tana River Forests (8) etc. Some species of globally threatened species occur in a variety of sites while other are restricted to a few selected sites. For instance Fischer'sTuraco has been recorded in the ten forest sites above; but Clarke's Weaver has only been recorded in Arabuko-Sokoke and Dakatcha Woodlands (Bennun and Njoroge, 1999; Zimmerman,

et al., 1996; Fry and Keith, 2004). Coastal forest birds restricted in a few sites are more in danger of local and global extinctions since most of these forests are being disturbed at an alarming rate (Burgess *et al.*, 2003).

The coastal forests represent a major regional ecological community characterised by distinctive land forms and plant species (Fishpool and Evans, 2001; Bennun and Njoroge, 1999). These forests in Kenya hold a significant number of bird species collectively classified as the African East Coast Biome species. In Kenya 30 bird species have been recorded (Bennun and Njoroge, 1999). Of the 30 species, 25 have been recorded at Arabuko-Sokoke (Bennun and Njoroge, 1999).

The coastal forests of Kenya also hold seven range-restricted species (Fischer's Turaco, Sokoke Scops Owl, Sokoke Pipit, Amani Sunbird, Clarke's Weaver, White-Winged Apalis *Apalis c. chariessa* (Vulnerable) and Tana River Cisticola *Cisticola restrictus* (Data Deficient). These are species whose total distributional area on earth is at most 50,000 km^2 (Fishpool and Evans, 2001; Stattersfield, *et al.*, 1998). This means that these coastal forests are an important refuge of these species; and whose disturbance or disappearance could directly lead to loss of these avian species.

The coastal forests birds of Kenya can be classified in three main categories in consideration to the levels at which each species relies on a forest habitat. Bennun *et al.*, (1996) have classified all forest birds into forest specialists, generalists and visitors. The forest specialists are the true forest birds, rarely occurring in non forest habitat, but

characteristic of the interior of little-disturbed forest, where they breed. They may persist in the secondary forest patches if their particular ecological requirement exist (Bennun and Howell, 2002). For instance, Tiny Greenbul *Phyllastrephus debilis* and Uluguru Violet-backed Sunbird *Anthreptes neglectus* which are forest specialists occur in the coastal forests. The larger the numbers of forest specialist in a forest is an indication of an existence of healthier forest.

The forest generalist are common in disturbed section of the forest such as the forest strips, gaps and edges but are rare in the interior of the close-canopy forest (Bennun and Howell, 2002). For example, the Mombasa Woodpecker *Campethera mombassica* and Chestnut-fronted Helmet-shrike *Prionops scopifrons* are generalist birds found in the coastal forests. Large numbers of generalists in a forest is an indication of a low quality forest habitat disturbed by various human activities. The forest visitors are birds which are often recorded in the forest, but are not depended upon it. They are common in non-forest habitat where they breed (Bennun and Howell, 2002). Scaly-throated Honeyguide *Indicator variegatus* and Crowned Hornbill *Tockus alboterminatus* both occurring in the coastal forests are forest visitors. The Absence of specialists and generalist bird species in a forest and replacement by the forest visitors is probably an indication that a forest habitat is altered or destroyed beyond the threshold levels of restoration through natural processes of succession or re-vegetation.

2.6 Some factors influencing diversity and distribution of forest birds

Birds, like all other animals are affected by the structure of their habitat which provides critical microhabitats for different function in their lifecycle (Musila, 1998). For example, large areas of pristine or less disturbed habitats are richer in native bird species. For example, Arabuko-Sokoke Forest which covers about 38,200ha of indigenous forest or thicket hold 25 East African Coastal Biome (EACBs) bird species, while the adjacent Gede Ruins National Monument (covering about 35 ha forest) has 12 (EACBs) Bennun and Njoroge, 1999). The density, richness and distribution of the bird species in a forest habitat is mainly influenced by the habitat structure, disturbance and fragmentation. Other factors include altitude, levels of predation through hunting and trade by local people or by other animals in the wild. The influence of habitat structure, disturbance and fragmentation on bird density, distribution and diversity are discussed below.

2.6.1 Habitat structure

Habitat structure is the gross external appearance of vegetation matter. The appearance is a product of the plant materials which occur in an area. The plant matter is influenced by soil characteristics, climate (rainfall amounts and patterns as well as temperature), altitude, rate and intensity of disturbance. In Kenya there are different forest types such as Afro-highland moorland-at above 3000-3800m above sea level on Mt. Kenya, arbardares etc; Highland dry forest occurring below 3000m above sea level on hill top of Mt. Marsabit, Chyulu Hills etc; Highland Moist forest occur between 1500-3000m above sea level for example in Kikuyu Forest etc; Coastal forests-occur at between <500m above

sea level with examples of Arbuko-Sokoke, Shimba Hills etc; Riverine Forest which occur along permanent and seasonal rivers such as the Tana River forests; and the Guineo-Congolian/Tropical rainforest-this is an evergreen or partially evergreen forest occurring in frost free areas below and about 1800m above sea level. Kakamega Forest in Western Kenya which occupies 0.1% of all existing forests in Kenya is the only example (Bennun and Njoroge, 1999).

The characteristics of each forest type determine the kind of forest bird species that are found in it. For example, the Chapin's Flycatcher *Muscicapa lendu* is a rainforest tropical forest endemic bird recorded in Kakamega Forest and not in any other forest type in Kenya (Bennun and Njoroge, 1999; Zimmerman *et al.*, 1996). However the species has been recorded in other rainforests in Uganda and Lendu Plateau in eastern Democratic Republic of Congo (Urban *et al.*, 1997). Taita Thrush *Turdus helleri* is an endemic species in Kenya recorded only in the Taita Hills (part of the Eastern Arc Mountains in Kenya (Zimmerman *et al.*, 1996; Sinclair and Ryan, 2003). The Spotted Ground Thrush is an intra-African migrant which prefers thick under storey of the coastal forests in Kenya during the wintering period in September (Zimmerman *et al.*, 1996; Sinclair and Ryan, 2003).

Therefore, habitat structure has a strong influence on bird species richness, density and distribution. The diversity of habitat niches and resources (food, water, cover for protection against predators and weather conditions) provided by a habitat determine the diversity of bird species (Cody, 1981). Additionally, different vegetation types show

variation in bird community assemblages. For example, forests supports more bird species than woodlands; while woodland are more rich in species than grasslands (Wilson, 1969), probably due to high habitat heterogeneity and diversity.

2.6.2 Habitat disturbance

Disturbance is the change in structure of a habitat. In a forest, disturbance mostly occurs through human activities such as selective or commercial logging, pit sawing, vegetation burning, charcoal burning, firewood collection, clearance of vegetation for cultivation, settlements, making trails, roads, or erecting of buildings. Given the needs of expanding human populations and the agricultural economies of many tropical countries, tropical forests will increasingly become fragments in agricultural landscapes (Beier *et al.*, 2002).

Birds as group are closely associated with forests, and approximately 30% of the world's species of birds are restricted to tropical forests (either for winter or year-round habitat); and that they would disappear if all tropical forests were lost (Myers, 1992). Therefore, the change in the structure of a forest through disturbance can have serious detrimental effects on avifauna survival. For instance, over half of all threatened bird species and one third of the global bird population considered at risk from habitat disturbance inhabit tropical forests (Birdlife International 2000; Gaston *et al.*, 2003). Specific feeding guilds of birds are either positively or negatively affected by forest disturbance. For example, frugivores (fruit eating birds) and insectivores (insect feeder) declined after disturbance, whereas granivores (seed eaters) increased (Gray, *et al.*, 2007). The abundance or richness of fruiting plants, for example, is associated with the diversity of frugivorous

bird species and their foraging behaviour (Moegenburg and Levey, 2003) and habitat choice (Levey, 1988). Human activities which selectively remove particular fruiting tree species which support a variety of frugivores might lead to decline in diversity and species richness. For example, insectivorous bird species are often the most species rich and abundant guild in tropical forests (Blake and Loiselle, 2001) and display considerable variation in feeding behaviour. The structural complexity and light regime of the habitat which undergoes considerable change following disturbance, may have important consequences for the search patterns of insectivores (Barlow *et al.*, 2002) or different groups of insectivores, such as bark-gleaners or dead-leaf probers (Rosenberg, 1993). Additionally, the removal of the dead wood is detrimental to forest biodiversity, since it affects the density and distribution of cavity nesting bird species due to the decline in quantity of holes and food (Waiyaki, 1995).

2.6.3 Habitat fragmentation

Fragmentation is the division of a contiguous habitat or ecosystem into two or more different isolated remnant patches. This happens when infrastructure (roads, building, campsites, airstrips, nature trails, transects etc) encroach on a pristine habitat. This creates 'islands' within the habitat matrix, which may negatively affect the survival of animal species. In the forest birds, population density, distribution and species richness are affected by habitat fragmentation (Donovan and Flather, 2002). This is because fragmentation changes the landscape through loss of original habitat via proliferation of human-dominated habitats and division of the original continuous habitat into isolated remnants patches (Pimm *et al.*, 2002).

Isolated patches may become far from one another in a way that they become un-reachable by individuals, and thereby lowering the pairing rate (Brooker and Brooker, 2003). Shy or less mobile species might have limited resources in the isolated patch, but be prevented by unsuitable matrix to disperse into the adjacent habitat. Lack of adequate food resources and mates might affect the reproductive capacity of birds. Fragmentation may also affect the availability of critical resources such as food in many ways. According to 'resource concentration hypothesis' (Root, 1973) there is a greater likelihood of critical resources being present in larger habitat patches resulting in higher population growth rates.

Therefore, the smaller a patch becomes through increasing edge effects the more likely it will decline in the quality and quantity of resources critical for survival of specific species. It has been shown that landscape change can result into dramatic changes in predator species assemblages, overall density of predators, and predator pressure on birds and their nests (Bayne and Hobson, 1997). Habitat feature such as cover is used for predatory avoidance by animals. The loss of cover through fragmentation might therefore, expose the prey to many predators, and consequently lead to increased loss of adult, off springs and eggs. Infrastructures such as roads with large traffic volume traversing habitats predispose birds, mammals and other taxonomic groups to accidental kills. Therefore, habitat fragmentation has serious negative effects on habitat quality and consequently avian community composition.

Surveys conducted by Waiyaki (1995) in Kaya Gandini recorded four (Fischer's Turaco, Spotted Ground Thrush, Sokoke Pipit and Plain-backed Sunbird) globally threatened bird species of which two (Fischer's Turaco and Sokoke Pipit) were range restricted. Two globally threatened bird species (Fischer's Turaco and Southern-banded Snake Eagle) were recorded at Kaya Mtswakara. A total of 46 and 34 bird species were recorded in Kaya Gandini and Mtswakara respectively. No bird surveys had been conducted at Mwache Forest Reserve. The three sites of different sizes (Kaya Gandini (about 150ha), Kaya Mtswakara (about. 247 ha) and Mwache Forest Reserve (about 345 ha) occur adjacent to one another, fragmented by natural boundaries of river valleys and internally by trails and foot paths used by locals to extract forest products, which might prevent faunal (birds) dispersal among different forest patches. The habitat structure and quality as result of the different levels of disturbance by human activities such as logging and firewood collection might determine the numbers of forest specialists, generalist birds and bird species richness found in each forest.

CHAPTER 3: METHODS AND MATERIALS

3.1 Introduction

This section covers information about the location where this research was conducted and characteristics of this area such as location, soils, vegetation, rainfall and conservation issues facing that area. Additionally, research methods used to collect data on birds such as Timed Species Count (TSCs), bird ringing and opportunistic surveys are covered. Methods used to collect data on vegetation and human activities and data organisation and analysis procedures are included.

3.2 Study Area-location and characteristics

This research work was conducted in three coastal forest sites in Kwale district (Kasemeni Division), southern Kenya: Kaya Gandini (150ha), Kaya Mtswakara (247 ha) and Mwache Forest Reserve (345 ha). They are approximately 15 km from Mombasa at 04°01'S, 39°30'E, and an altitude of 140 - 200M above the sea level (Fig. 1). They are all listed within the Eastern Arc and Coastal (Kenya and Tanzania) Forests Biodiversity Hotspot (Burgess, *et al.*, 2003); additionally, Kaya Gandini is an Important Bird Area (IBA). They occur at close proximity to each other with Mbome/Gandini River separating Gandini and Mtswakara Kayas, while Mwache River and Mwache Creek adjoining Mtswakara and Mwache Forest Reserve.

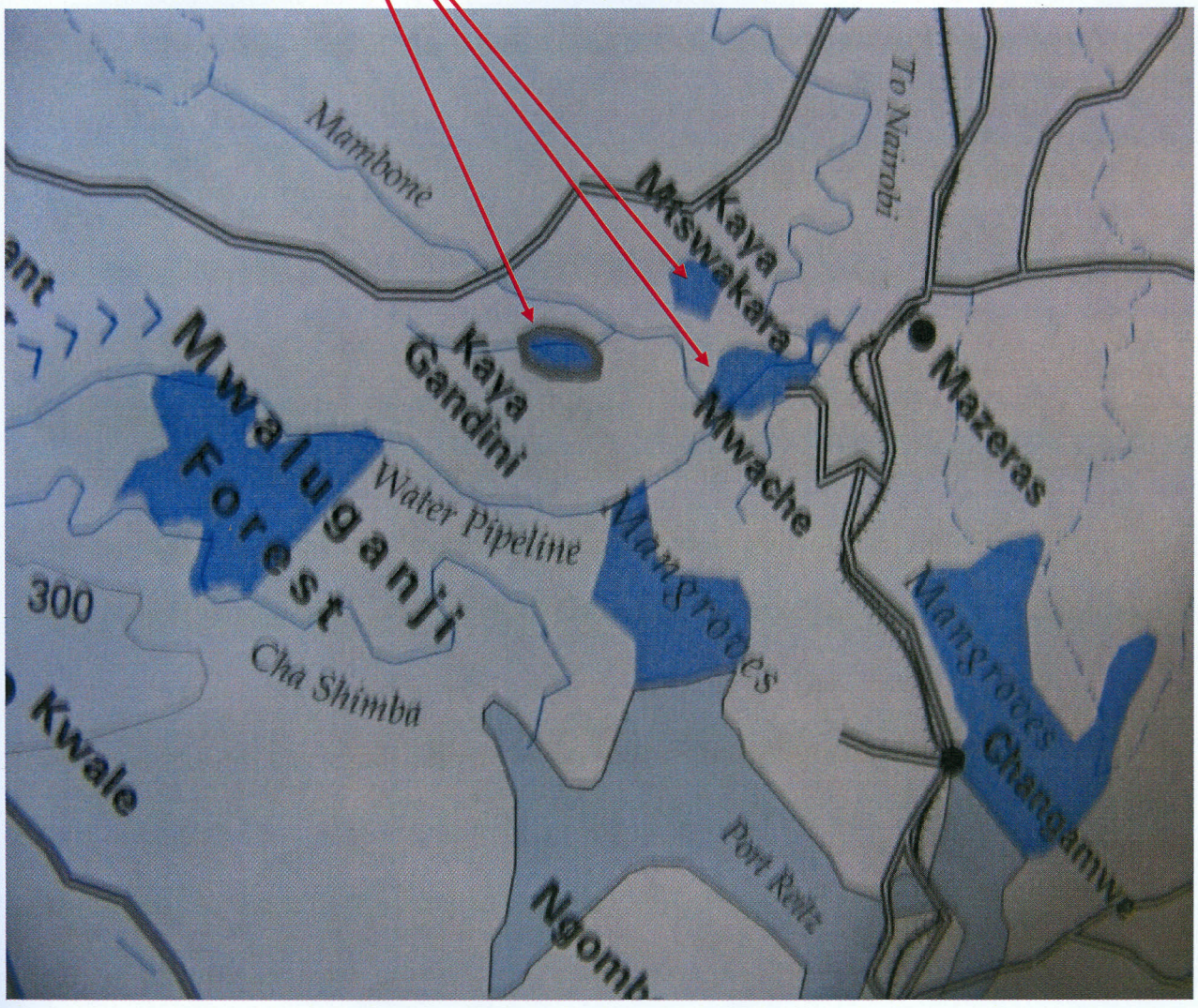

Fig 1: *Map of Kenya showing the locations of the three study areas as indicated by the arrows*

3.2.1 Soils

Geologically, the coastal forest strip has been subject of considerable tectonic activity, sedimentation and erosion associated with movement of shoreline (Burgess and Clarke, 2000). Kaya Gandini and Mtswakara have Duruma/Kambe sandstone type of soils (Waiyaki, 1995). The three sites have different soil types even within one fragment. Mwache forest has black soils on the eastern part and loamy soils in areas of thick vegetation cover with large percentage of litter cover. Fifty percent of Kaya Mtswakara has Duruma/Kambe sandstone which produces red soils that spread to the neighbouring Kaya Gandini covering 30% of this forest. Kaya Gandini has about 50% of loamy soils not deeper than a metre most likely influenced by the decomposition of litter found in 60% of the fragment which has thick vegetation cover. The soils in the sites are well drained indicating that they contain large percentage of sand.

3.2.2 Rainfall

The area has bimodal rainfall pattern with short rains occurring between October-December and long rains in between March-July. The average annual rainfall ranges between 400-1200mm (Ityeng *et al.*, 2008). Even though Axelrod and Raven (1978) noted that climatic conditions had been relatively stable in the past, recently there have been a considerable fluctuations from year to year probably influenced by the current effects of climate change leading to frequent and unexpected droughts and floods. This research was conducted in between late October 2007-March 2008, which was the dry period of the year. A rapid survey of nocturnal birds was also done between 17th-26th August 2008, the beginning of a short dry period after the end of the long rains.

3.2.3 Temperature and Winds

The minimum and the maximum temperature were 22.9^0 C and 32.1^0 C respectively, with an average of 27.4^0 C. Because the study areas bordered the Indian Ocean on one side, they had a high average percentage humidity of 75.1. The high fluctuations in sea tide levels led to frequent blowing of strong winds averagely 13.7km/h over the study areas (http:TuTiempo.net, 2008).

3.2.4 Vegetation

The vegetation of three forest patches was dry deciduous *Cynometra-Terminalia* forest community (Robertson and Luke, 1993). The three sites do not have stands of distinct dominant vegetation type characterised by one or more tree species but comprised of a mixture of species such as *Brachystegia spiciformis*, *Cynometra webberi*, *Afzelia quanzensis* etc as recorded by Robertson and Luke (1993). However, Kayas; Gandini and Mtswakara had few Baobabs trees *Adansonia digitata* localized around the sacred groves in the fragments, but were lacking in Mwache Forest Reserve.

3.2.5 Other Animals

The three forests were devoid of large mammals, but a few small mammals and primates were recorded by sight and signs of presence (mostly burrows). The Four-toed Elephant-Shrew *Petrodromus tetradactylus* was recorded in Kaya Gandini. Vervet Monkey *Cercopithecus Aethiops*, Blue Monkey *Cercopithecus mitis* and Angolan Black and

White Colobus Monkey *Colobus angolensis palliates*. The Black and White Colobus monkeys were more common in Gandini than in Mwache and Mtswakara. Other big mammals recorded were the Bush Pig *Potamochoerus larvatus* and Aardvark *Orycteropus afer*. A suni *Neotragus moschatus* was recorded in Mwache Forest Reserve. There was human-wildlife conflict with the following animals: The Vervet Monkey and Olive Baboon *Papio anubis* were involved in destruction of ripe maize, while Bush Pigs were eating cassavas and groundnuts. As a result the local people especially those living adjacent to the forests spent many hours both at night and day guarding their crops, avoided planting targeted crops or just abandoned their farms. There were a variety of invertebrates (insects, spiders, molluscs etc) and reptiles and amphibians in these sites were not identified to species level.

3.2.6 Socio-economic Issues

The communities living around forests were involved in different economic activities. Majority (about 60%) were farmers who cultivated maize, cassava, coconut trees, ground nuts and cashew nuts on an estimated 2ha of garden per/household. About 5% were keeping few animals (goats, sheep, cows and poultry). The animals were mostly grazed in the forests or in fallowed areas where they were tethered. About 2% were fishermen involved in collecting fish, prawns and crabs from the Mwache Creek. More than 10% of the local people were employed locally as teachers or in the nearby towns (Mombasa, Mazeras, Miritini, Kinango, Kwale etc). Kasemeni Division the focal point of this study occurs in Kwale District (Ityeng *et al.*, 2008). The district has an annual human population growth of 2.6, with a mean household size of 6-8 people. The district occurs

in Kinango constituency the poorest in Kenya (Ityeng *et al.*, 2008). The main factors causing the high human poverty in the area include unreliable and erratic rainfall, poor farming practices and low livestock holding capacity (Ityeng *et al.*, 2008). The high levels of poverty have led to dependence on unsustainable exploitation of forest products from the three forests. The main products extracted by the local community for household use and commercial purposes included building poles, timber, firewood and some medicinal plants.

3.3 Research Methods

3.3.1 Reconnaissance survey

Three days were spent in each fragment walking in and around the forest familiarising with terrain, vegetation, habitat types, different foot paths and birds. The vegetation in each fragment was categorised in three different types based on levels of disturbance or degradation and uniqueness. These vegetation types included; a) aquatic habitat- comprising of river (Mwache and Mbome Rivers) basins and creek separating Mwache Forest Reserve from Kaya Mtswakara; b) primary habitat- remaining least disturbed typical coastal forest areas in the three sites covered by indigenous tree species and shrubs; c) secondary habitat-highly disturbed sections of the forests cleared of vegetation, bare or regenerating with grass, few scattered native trees, shrubs or planted with exotic plants. The size of each habitat type was visually estimated in each forest. Detailed avian (bird ringing and Timed Species Counts (TSCs) and vegetation surveys were restricted in the primary habitat sections of the three forest fragments, because this represented the remaining indigenous habitat along the coastal forests; was expected to host majority of

birds typical of this biome and therefore, would enable easier comparison of data among the different sites. All field methods (bird and vegetation survey methods) were tested and research assistants were trained on data collection procedures. Camping sites were identified and logistics of accessing three study sites developed. Birds were surveyed using Timed Species Counts (TSCs), bird ringing/banding and opportunistic methods.

3.3.2 Timed Species Counts (TSCs)

The TSCs were initially developed for use in savannah habitats (Pomeroy and Tengecho, 1986). However, a modified fashion of TSCs was developed and tested (Bennun and Waiyaki, 1992a) and accepted as an effective and rapid method of counting birds using the mid and upper canopy of the forest (Bennun and Waiyaki, 1993). Detailed bird surveys in this study were concentrated in the primary habitat section of each forest fragments, which had network of footpaths used by the local people to facilitate comparison of data among the different sites. The observer walked quietly for a period of 40 minutes (Waiyaki, 1995; Bennun and Howell, 2002), a long a particular path at a bird watchers pace, stopping frequently to identify and record all birds seen or heard calling. Additional information recorded for each contact was number of individuals, perching or flying height, distance (within or beyond 25m), time and type of contact. Counts were started at dawn (06; 00hr) and ended at ten when bird activity drops dramatically (Waiyaki, 1995; Fanshawe, 1993) in the coasts of Kenya. A total of 22 TSCs were conducted over a period of seven mornings across the primary sections of the three sites.

3.3.3 Bird Ringing/Banding

Mist netting or bird ringing is an effective method of surveying quiet and skulking species of the forest under storey, which are unlikely to be recorded using other techniques (Bibby *et al.*, 1998; Bennun and Howell, 2002). Bird banding was done in the primary sections of the forest fragments. In Kayas; Gandini and Mtswakara ringing sites were established around the sacred groves (the most 'holy section of the forest with very minimal habitat disturbance where traditional ceremonies were conducted by the local Duruma people). In Mwache Forest Reserve, which lacked a sacred grove, an area about 500m from the quarries in the eastern side of the forest was selected for having relatively least disturbed indigenous habitat like that in Kayas. The ringing sites were 200-500m from each other following the existing trails which were cleared of vegetation using machetes to one metre width. Two net lines of 60m (18m x 2 and 12m x 2) and 54m (18m x 3) placed at a distance of 60-100m, were established in each ringing site. Three ringing sites were used to collect bird ringing data in each forest (Laurence, *et al.*, 2004). Ringing was done in each forest for four hours (0545-1015hr) for two consecutive days and twice in each forest making a total of 12 days and 48 hours spent in each fragment. Nets were checked every one hour and furled overnight or during heavy downpour. All captured birds were extracted and fitted with a uniquely numbered aluminium metal ring in one leg and a single coloured plastic ring (red-for Gandini, yellow for Mtswakara and Blue for Mwache) to determine species dispersal among the patches. Additional biometric measurements taken were length of head, tarsus, wing, bill, weight and moult scores.

3.2.4 Opportunistic Bird Surveys

The method involved compiling throughout the survey period a comprehensive checklist of birds of an area being surveyed. In this study all different habitats in each forest fragment were visited as well as the surrounding habitats about 300m radii around each site. Nocturnal (owls and nightjars) bird surveys were also done for in each forest for two nights. Birds were identified by sight and confirming records using the a bird identification guide of Kenya and Northern Tanzania by Zimmerman, *et al.*, (1999); and using calls based on bird watching experiences of the observers.

3.3.5 Vegetation Surveys

Vegetation data was collected around net lines along foot paths used in birds survey in the primary habitats of the three forest fragments. Ten plots each of $10m^2$ were marked 10m perpendicularly away from foot paths and 50m from each other around each net line in each forest. A total of 30 plots were used to collect data around the mist netting areas in each forest fragment. Additional vegetation data was collected within 50 plots along footpaths used during Timed Species Counts (TSCs) surveys. Canopy height was estimated visually to the nearest meter as the vegetation above 4m. Canopy cover was estimated by recording the percentage of the sky obscured from the view by vegetation above using a toilet roll (11cm long, 4.5 cm diameter). The gross vegetation was estimated in percentage within a vertical cylinder of 10m diameter divided in three vegetation levels; low (0-2m), middle (3m-8m) and high (>8m). All live and cut tree stems were counted within a 5m radius from the centre of the plot in categories of 5-10cm Diameter at Breast Height (DBH), 11-20cm, 21-30cm and >31cm (Fanshawe, 1993; Waiyaki, 1995). Measures of litter, herb and bare cover were estimated in

percentage within 1 m^2 plot placed 1m from the centre of the plot in the northern quarter. To measure the spacing and sizes of canopy trees the closest four trees (>8m tall) were located from the centre of the plot, one in each quadrant of the compass (North, East, West and South) direction. The distance to each tree was estimated in metres by pacing and Diameter at Breast Height (DBH) of the tree measured using a ruler. Shrub density (under storey thickness and openness) was measured at 1m and 2m height, using a chequerboard (50cm by 50cm with 10cm by 10cm red and white squares), at five metres from the centre of the plot directly North and South of the compass bearing (Fanshawe, 1993; Waiyaki, 1995). I took all the measurements myself to reduce biases in observations.

3.3.6 Interviews and Observation of Human Activities

Oral interviews were conducted with Kaya elders and community forest guards in charge of Kaya Gandini and Kaya Mtswakara and locals (men and women) living adjacent to study areas and others found in the study sites extracting some forest products or grazing animals. Open-ended questions (Frost and King, 2003) were used to collect information about the status of the management of Kayas forests, extraction of forest products by local people, human encroachment into the forests and community participation in conservation of the forest sites. A forest guard based at Mwache Forest Reserve provided useful information about quarrying activities in this fragment. The information generated through interviews was validated by many field observations recorded during numerous visits into each forest, my interactions with members of the community in the surrounding villages and literature reviews.

3.4 Data Organisation and Analysis

Bird species richness, feeding guild compositions and vegetation structure of the three fragments were summarized and compared among the three sites. Bird species recorded were categorised into their dependence (forest specialist, generalist and visitors) on the forest following classifications provided by Bennun *et al.*, (1996). The relative abundance of each species was calculated by using all birds contacts recorded within 25m from the observer and above three metres from the ground (Bennun and Howell, 2002). Chi-square was used to determine the differences in proportion of bird feeding guild compositions among the three forest sites. Vegetation data entries and organisation was done in Ms excel 2003 spreadsheets. Count data with zero observations and percentages were log (x+1) and arcsine transformed respectively to normalise the data sets. The data was imported into Statistical Package for the Social Sciences (SPSS) 12.0 for Windows for detailed analysis. One way ANOVA followed by Post Hoc multiple comparison Turkey test for variables which were significantly different among the three sites was used (Lowler and Cohen, 1990). A detailed description of the status of the management of Kayas forests, extraction of forest products, human encroachment into the forests, community participation in conservation of the forest sites and quarrying activities at Mwache Forest Reserve was compiled from interviews and ad-hoc field observations.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

The chapter on results present findings from empirical data collected from the field and analysed. It covers the four objectives in chapter one. The first section of this chapter is an inventory of bird species including the status of East Africa Coastal Biome (EACBs) bird species and Globally Threatened (GTbs) bird specie, bird dispersal within different fragments, relative abundances of bird species and bird feeding guilds compositions. The following section covers results on habitat characteristics such as different vegetation structures, comparison of vegetation variables among different fragments, relationship among vegetation variables and levels of logging and regeneration. The section on vegetation structures is followed by a detailed descriptions of the current conservation status of the forest fragments specifically; the status of the management of these forests and threats faced by them such as extraction of forest products by local people, human encroachments and rock quarrying; as well as community participation in conservation of these forests. The final section of this chapter is discussions which provides an in depth analyses of the current results and how they fit on or disagree with the wider context of existing biological information.

4.2 Birds

4.2.1 Bird Species Richness

A total of 141 bird species were collectively recorded in the three sites (Appendix 1). Out of these 93 species were recorded in Kaya Gandini, while Kaya Mtswakara and Mwache Forest Reserve had 88 and 91 species respectively. These were species recorded in the inn different habitats (primary, secondary and aquatic/wetland habitats) in each forest fragment. Of the 93 species in Gandini, 50 were recorded in the primary habitats of that forest, while 51 and 31 were respectively recorded in the primary habitats of Mtswakara and Mwache. Out of 141 species, 41 (29% of all species) common species types were observed in each of the three fragment. These represented 44%, 47% and 45% of all species recorded in Gandini, Mwache and Mtswakara respectively. Gandini and Mtswakara had the largest number (61) of species recorded in two sites, followed by Mwache and Mtswakara (58) and Mwache and Gandini (53) (figure 2).

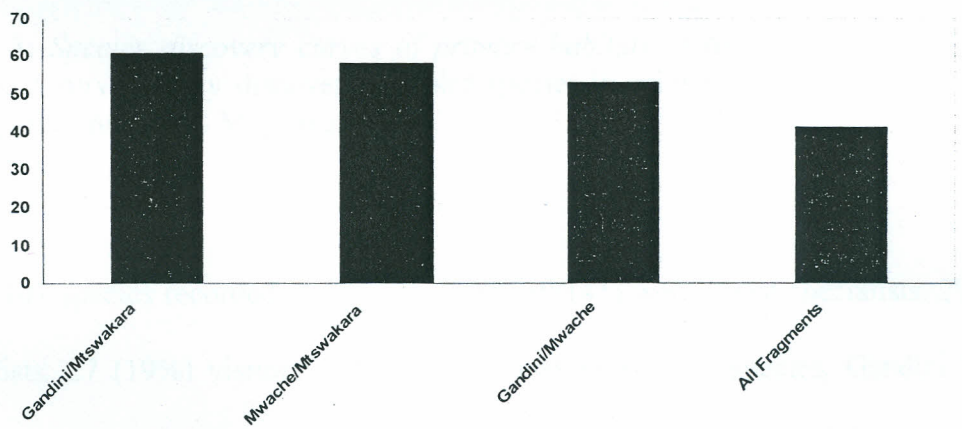

Figure 2: *The number of common bird species observed in two different fragments.* These were the species found overlapping (some species occurring in more than one site) in different sites. Gandini and Mtswakara had the highest number of common bird species.

The species discovery curves of Gandini and Mtswakara for the primary forest habitats began to level off on the fifth day when increased searches was unlikely to record new additional species in the two fragments. The curve of Mwache on the other hand slightly levelled off on day seventh (Figure 3), indicting that additional avian surveys might record some new bird species.

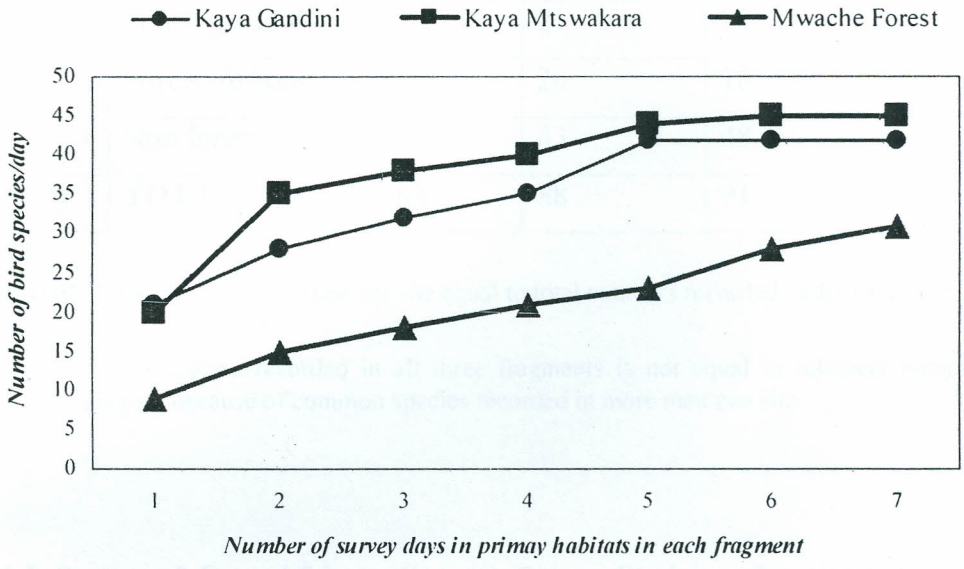

Figure 3: *Species discovery curves of primary habitats of the three forest fragments.* Additional surveys may discover new bird species in primary habitats of Mwache but unlikely in Gandini and Mtswakara.

Out of 141 species recorded in all sites, 9 (6% (9/141) were forest specialists, 29 (21%) generalists, 27 (19%) visitors and 76 (54%) non forest bird species. Gandini had the highest numbers of specialist species (Table 1). There were more (34 species) forest species (specialist and generalists combined) recorded in Gandini than Mwache and Mtswakara where same (25 species) number were recorded. There was a significant differences among specialists (X^2_{test}, P=17.37, 2 d.f), generalists (X^2_{test}, P=55.94, 2 d.f),

isitors ($X^2_{test.}$ P=51.36, 2 d.f) and non-forest birds ($X^2_{test.}$ P=146.6, 2 d.f) in different orest fragments.

Table 1: *Summary of different forest bird species categories in the forest fragments*: More forest birds occurred in Gandini than other fragments while Mwache was richer in non-forest birds).

	Bird categories	Gandini	Mtswakara	Mwache	TOTALS**
1	Forest specialists	8	4	5	9
2	Forest generalists	26	21	20	29
3	Forest visitors	21	20	18	27
4	Non forest birds	38	43	48	76
	TOTALS*	**93**	**88**	**91**	**141**

Legend: * total species recorded per site equal to total numbers recorded under each category

**total species recorded in all three fragments is not equal to numbers recorded under each category because of common species recorded in more than one site.

4.2.2 Status of East African Coastal Biome Bird Species (EACBs) and Globally Threatened Bird Species (GTbs)

Four globally threatened birds (Fischer's Turaco, Southern Banded Snake Eagle, Plain-backed Sunbird and Sokoke Pipit) were recorded in the three sites. Gandini had four species, Mtswakara two species (Fischer's Turaco and Plain-backed Sunbird) and Mwache three species (Fischer's Turaco, Plain-backed Sunbird and Sokoke Pipit (Table 2). The Spotted Ground Thrush previously recorded in Gandini was not sighted. The thrush was not recorded in Mwache and Mtswakara. Fischer's Turaco was more abundant in Gandini where its calls could be heard almost every day in the morning in the primary habitat. The turacos were rare in Mwache and Mtswakara and where it was observed or

heard at most twice throughout the study period. Plain-backed Sunbird was recorded in the sacred grove (primary habitat) of Gandini and mostly in the primary habitats of Mwache and Mtswakara. Southern Banded Snake Eagle and Plain-backed Sunbird were recorded in Gandini and Mtswakara respectively for the first time. Southern Banded Snake Eagle and Sokoke Pipit were very rare and were recorded only once in Gandini. The Southern Banded Snake Eagle previously recorded in Mtswakara in the past was not recorded in this site.

Table 2: *Summary of globally threatened birds in the fragmented forests*

	Globally threatened bird species	**Gandini**	**Mtswakara**	**Mwache+**
1	Fischer's Turaco	R*	R*	R
2	Southern Banded Snake Eagle	R**	NR	NR
3	Plain-backed Sunbird	R*	R**	R
4	Sokoke Pipit	R*	NR	R
5	Spotted Ground Thrush	NR	NR	NR
	TOTAL (species recorded)	**4**	**2**	**3**

Legend: Species previously recorded (*), spp not recorded in the past (**), surveys done at the site for the first time (+), R-recorded, NR-not recorded.

A total of 14 East African Coastal Biome Bird Species (EACBs) representing c. 10% of all species in the three sites were recorded. This number represented a 47% (14/30 East Africa Coastal Biome bird species) of coastal biome species found in Kenya. Gandini and Mwache had the same number of EACBs while Mtswakara was less rich in species (Table 3).

Table 3: The number of East African Coastal Biome Bird Species (EACBs) recorded in the fragmented forests.

	Bird species	Gandini	Mtswakara	Mwache
1	Black-bellied Starling	R	R	R
2	Brown-breasted Barbet	R	R	-
3	Brown-headed Parrot	R	R	R
4	Fischer's Greenbul	R	R	-
5	Fischer's Turaco	R	R	R
6	Mombasa Woodpecker	R	R	R
7	Mouse-coloured Sunbird	-	-	R
8	Northern Brownbul	-	R	R
9	Plain-backed Sunbird	R	R	R
10	Southern Banded Snake Eagle	R	-	-
11	Scaly Babbler	-	-	R
12	Chestnut-fronted Helmet Shrike	R	-	
13	Zanzibar Red Bishop	-	-	R
14	Sokoke Pipit	R	-	R
	TOTALS (species recorded)	**10**	**8**	**10**

Legend: (R)-recorded, (-) not recorded

Black-bellied Starling *Lamprotornis corruscus mandamus*, Brown-headed Parrot *Poicephalus cryptoxanthus* and Mombasa Woodpecker *Campethera mombassica* were more common in fragments where they were recorded. Brown-breasted Barbet *Lybius melanopterus*, Fischer's Greenbul *Phyllastrephus fischeri*, Fischer's Turaco, Mouse-coloured Sunbird *Nectarinia veroxii*, Northern Brownbul *Phyllastrephus strepitans* and Zanzibar Red Bishop *Andropadus importunes* were uncommon in forests where they were recorded. Sokoke Pipit, Plain-backed Sunbird, Scaly Babbler *Turdoides aylmeri kenianus*, Southern Banded Snake Eagle and Chestnut-fronted Helmet-shrike *Prionops scopifrons kirki* were very rare and were either seen or heard calling once where they were recorded.

4.2.3 Bird Dispersal Within Fragmented Forests

A total of 59 individuals of 12 species were captured and fitted with both aluminium and plastic coloured ring in the three forest fragments. Gandini had the largest number (10) of species and individuals while Mtswakara (4) and Mwache (3) had very few species. Red-capped Robin Chat *Cossypha natalensis* (26) and Eastern-bearded Scrub Robin *Cercotrichas q. quadrivirgata* (5) had the largest numbers of individuals recorded in Gandini (Table 4). When Red-capped Robin-chat were omitted from the analysis because they are Afro-tropical migrant species occurring in Kenya between April-November (not available in some sites when ringing was being done) annually (Zimmerman, *et al.*, 1996), Gandini still had higher species richness and abundances. No individuals of a particular species was captured or observed in a different fragment than the one in which it was initially ringed. This means no ringed individual was observed dispersed from one fragment to the other.

Table 4: *List of bird species ringed in the three fragments*

	Bird species	**Gandini**	**Mtswakara**	**Mwache**	**Totals**
1	Red-capped Robin Chat	26	2		**28**
2	Eastern Nicator	5	2	2	**9**
3	Eastern-bearded Scrub Robin	5	1	2	**8**
4	Narina Trogon	3	-	-	**3**
5	Olive Sunbird	1	-	-	**1**
6	Red-tailed Ant Thrush	1	-	-	**1**
7	African Goshawk	1	-	-	**1**
8	Yellow-bellied Greenbul	1	-	-	**1**
9	Blue-mantled Crested Flycatcher	1	-	-	**1**
10	Tambourine Dove	1	-	1	**2**
11	Ashy Flycatcher	2	-	-	**2**
12	Collared Sunbird	-	2	-	**2**
	TOTALS (individuals)	**47**	**7**	**5**	**59**

Legend; (-) not recorded/captured

.2.4 Relative Abundances of Bird Species

)nly 49 species in all sites met conditions provided for analysis of TSCs data in a forest ituation as provided by Bennun and Howel (2002) and Pomeroy and Tengecho (1986).)f these 29 species were from Gandini, 33 in Mtswakara and 27 from Mwache Appendix 2). 12 species occurred in all three sites, with seven of these forest species aving the highest abundance score found in Gandini, while three were in Mtswakara and two in Mwache. Grey-backed Camaroptera *Camaroptera brevicaudata* was the most abundant at Gandini but was replaced by Eastern-bearded Scrub Robin in Mtswakara and Mwache. Other species which were relatively abundant throughout the three fragments were Eastern Nicator *Nicator gularis*, Olive Sunbird *Nectarinia olivacea* and Collared Sunbird *Anthreptes collaris garguensis*. The rarest (with the lowest abundance score) species in Gandini were Little Sparrowhawk *Accipiter minullus*, Brown-headed Parrot and Great Sparrowhawk *Accipiter melanoleucus*. The Green Wood Hoopoe *Phoeniculus purpureus*, Martial Eagle *Polemaetus bellicosus* and Plain-backed Sunbird were uncommon in Mtswakara while Northern Brownbul and African Paradise Flycatcher *Terpsiphone viridis* were rare in Mwache.

There were six forest specialists (FF) analysed for relative abundance. Of these, Olive Sunbird was recorded in all fragments and most abundant in Mtswakara. Red-tailed Ant Thrush *Neocossyphus rufus* and African Crowned Eagle *Stephanoaetus coronatus* were only recorded in Gandini and Mtswakara respectively but with very low relative abundances (Table 5).

Table 5: *Relative abundances of forest specialist (FF) birds in three fragmented forests*

	Bird Species	Gandini	Mtswakara	Mwache
1	Olive Sunbird	3.00	3.45	2.64
2	Black-headed Apalis	2.73	2.14	-
3	Fischer's Greenbul	2.45	2.36	-
4	Red-tailed Ant Thrush	2.18	-	-
5	Plain-backed Sunbird	-	2.05	2.18
6	African Crowned Eagle	-	-	2.14
	Total (species recorded)	**4**	**4**	**3**

Legend; (-) not recorded

Seventeen forest generalist species (F) were analysed for relative abundances in the three sites. Of these, six species were recorded in all fragments and the other in one or two sites (Table 6). Eastern Nicator, African Goshawk *Accipiter tachiro*, Yellow-bellied Greenbul *Chlorocichla flaviventris*, Mombasa Woodpecker and Great Sparrowhawk were most abundant in Gandini, while Collared Sunbird was more abundant in Mtswakara. Tambourine Dove *Turtur tympanistria*, Black-backed Puffback *Dryoscopus cubla* and Crested Guineafowl *Guttera pucherani* were more abundant in Mwache (Table 6)

Table 6: *Relative abundances of forest generalist (F) birds in three fragmented coastal forests*

	Bird Species	Gandini	Mtswakara	Mwache
1	Eastern Nicator	3.09	3.05	2.73
2	African Goshawk	2.95	2.18	2.18
3	Trumpeter Hornbill	2.55	-	-
4	Yellow-bellied Greenbul	2.73	2.32	2.23
5	Collared Sunbird	2.55	2.95	2.64
6	Mombasa Woodpecker	2.36	2.18	2.27
7	Ashy Flycatcher	2.23	2.18	-
8	Fischer's Turaco	2.23	-	-
9	African Wood Owl	2.09	2.09	-
10	Greater Sparrowhawk	2.09	2.05	2.14
12	Brown-headed Parrot	2.05	-	-
13	Mottled Spinetail	-	2.18	-
14	Fiery-necked Nightjah	-	2.09	2.36
15	Tambourine Dove	-	-	2.14
16	Black-backed Puffback	-	-	2.18
17	Crested Guineafowl	-	-	2.18
	Total (species recorded)	**11**	**10**	**10**

Legend; (-) not record

Six coastal biome species were analysed for relative abundances. Mombasa Woodpecker occurring throughout the three sites was more abundant in Gandini, followed by Mwache and finally Mtswakara (Table 7).

Table 7: *Relative abundances of East African Coastal Biome Bird Species (EACBs) in the three fragments*

	Bird Species	Gandini	Mtswakara	Mwache
1	Fischer's Greenbul	2.45	2.36	-
2	Mombasa Woodpecker	2.36	2.18	2.27
3	Fischer's Turaco	2.23	-	-
4	Brown-headed Parrot	2.05	-	-
5	Plain-backed Sunbird	-	2.05	2.18
6	Northern Brownbul	-	-	2.05
	Total (species recorded)	**4**	**3**	**3**

4.2.5 Bird Feeding Guilds Compositions

The forest birds (specialists and generalists) including visitors totalling 65 species recorded in TSCs counts were considered in analysing for bird feeding guilds compositions. The three sites were rich in insectivores representing 49%, followed by carnivores (15%), granivores (11%), omnivore (9%) and frugivores and nectarivores each 8%. Gandini was richer in insectivore species (45%) $X^2_{test.}$ P=76.62, 5 d.f) than Mwache and Mtswakara each having 31% (Table 8). There was a significant difference among carnivores ($X^2_{test.}$ P=25.38, 5 d.f) in different forest sites. There was no difference in the numbers of frugivores, granivores, nectarivores and omnivores recorded in different forest sites.

Table 8: *Bird feeding guilds compositions for the three forest fragments*

Feeding guilds	Gandini	Mtswakara	Mwache	TOTALS**
Carnivore	9	8	5	**10**
Frugivore	5	4	3	**5**
Granivore	4	4	5	**7**
Insectivore	29	20	20	**32**
Nectarivore	4	4	5	**5**
Omnivore	4	5	5	**6**
TOTALS*	**55**	**45**	**43**	**65**

Legend: * Total species recorded in each site equal to numbers recorded under each category

**total species recorded in all three fragments is not equal to numbers recorded under each category because of common species recorded in more than one site.

4.3 Vegetation Structure

4.3.1 Summary of Vegetation Structure

Table 9: *Summary of vegetation variables in the three forest sites.*

	Variable	N=80plots/site	MWA	GAN	MTS	P-values
1	Canopy Cover	Mean	19.88±3.07	40.09±3.51	39.28±3.17	0.0007*
2	Canopy Height	Mean	3.81±0.46	17.10±3.17	12.39±0.92	0.0008*
3	Lower Canopy Cover (0-2m)	Mean	35.94±1.62	40.38±1.71	41.69±2.36	0.089
4	Medium Canopy Cover (3-8m)	Mean	19.38±1.68	15.13±1.08	9.81±1.01	0.0002*
5	High Canopy Cover (>8m)	Mean	1.38±0.37	9.38±1.14	6.58±0.71	0.0085*
6	Tree Distance (m)	Mean	7.29±0.49	7.35±0.300	7.03±0.46	0.859
7	Diameter at Breast Height (DBH (m)	Mean	18.93±1.14	34.72±1.46	28.99±1.19	0.0002*
8	Live Stems (5-10cm)	Count	134	130	84	0.380
9	Live Stems (11-20cm)	Count	59	62	69	0.712
10	Live Stems (21-30cm)	Count	29	65	73	0.0002*
11	Live Stems (>31cm)	Count	16	47	61	0.0002*
12	Dead Standing Stems (5-10cm)	Count	0	1	0	0.369
13	Dead Standing Stems (11-20cm)	Count	2	0	1	0.366
14	Dead Standing Stems (21-30cm)	Count	0	1	0	0.369
15	Dead Standing Stems (>31cm)	Count	0	2	1	0..366
16	Dead Floor Stems (5-10cm)	Count	7	9	1	0.255
17	Dead Floor Stems (11-20cm)	Count	3	4	1	0.408
18	Dead Floor Stems (21-30cm)	Count	0	2	0	0.369
19	Dead Floor Stems (>31cm)	Count	0	1	1	0.607
20	Cut Stumps (5-10cm)	Count	255	335	331	0.207
21	Cut Stumps (11-20cm)	Count	19	32	61	0.0001*
22	Cut Stumps (21-30cm)	Count	6	21	15	0.44
23	Cut Stumps (>31cm)	Count	3	12	10	0.160
24	Vegetation Density at 1m	Mean	57.28±2.19	57.05±2.64	50.25±3.22	0.118
25	Vegetation Density at 2m	Mean	54.65±2.39	54.95±2.74	56.93±3.08	0.817
26	Litter Cover	Mean	75.80±2.22	74.63±2.55	62.56±3.16	0.103
27	Bare Cover	Mean	16.11±1.70	19.13±2.44	26.49±2.90	0.786
28	Herb Cover	Mean	8.15±1.55	6.25±0.83	10.56±1.70	0.101

Legend: MWA-Mwache, MTS-Mtswakara, GAN-Gandini and SIL-significant level, * variables which are significantly different among sites.

4.3.2 Forest Litter Cover, Under-storey (0-3m) and Canopy (>4m) cover

The forest floor of the three sites was covered with a lot of litter, with limited herbs (weeds) and bare cover (open areas). However, there was no significant difference in cover of litter, herbs and bare ground in the three forest fragments (Table 9). The lower vegetation thickness was the same among the three forests, while the degree of openness at 1m and 2m was the same. The canopy cover (CC-above 4m) and high canopy cover (HCC-above 9) of Gandini and Mtswakara was the same and different from that of Mwache (Table 10). The Medium Canopy Cover (MCC-(3-8m) was the same between Gandini and Mwache and different from Mwache (Table 10).

4.3.3 Comparison of Vegetation Structure Among Forest Fragments

The vegetation structure of the three fragments was 71% (20/28 of variables collected) similar and only 29% (8/28) dissimilar. Canopy cover, canopy height, high canopy cover, mean diameter of trees, live stems Diameter at Breast Height (DBH) 21-30cm and >31cm was the same for Gandini and Mtswakara but different for Mwache. Medium canopy cover and cut stumps DBH 11-20cm was the same for Ganidini and Mwache. Overall 26 (93% (26/28) variables were the same in Gandini and Mtswakara meaning the two sites were more similar in vegetation structure than Mwache (Table 10).

Table: 10 *Comparisons of means of vegetation variables among the forest fragments* (n-80/plot, Turkey test for all variables with significant difference using one way ANOVA (S-Same, D-different).

	Variables	Mwache	Gandini	Mtswakara
1	Canopy cover (%)	D	S	S
2	Canopy height	D	S	S
3	Medium canopy cover (3-8m)	S	S	D
4	High canopy cover (>8m)	D	S	S
5	Mean DBH (m) of trees	D	S	S
6	Live stems DBH 21-30cm	D	S	S
7	Live stems DBH >31cm	D	S	S
8	Cut stumps DBH 11-20cm	S	S	D

4.3.4 Relationship Among Vegetation Variables

Canopy cover in the forest was influenced by diameter of trees, canopy height, live and cut big trees (>31cm). This relationship was significant ($F_{4, 235}=113.620$, $p<0.0009$, $r^2=0.659$). 65.9% of these variables explained the changes in canopy cover among the forest fragments. Litter cover in the forest floor was predicted by medium canopy cover, canopy cover, under-storey vegetation cover at (1m and 2m) and lower canopy cover. This relationship was significant ($F_{5, 234}=38.18$, $p<0.0001$, $r^2=0.449$). 44.9% in variability in litter cover was explained by these variables.

4.3.5 Levels of Regeneration and Logging

There were different levels of logging (removal of live trees evidenced by existence of stumps) and regeneration (standing live trees) of different tree sizes in each different forest. The rate of logging and regeneration was calculated by summing up numbers of live trees and cut stumps of each Diameter at Breast Height (DBH) category in 80 plots

surveyed in each forest. The percentage rate of logging or regeneration was calculated by dividing the number of live trees or cut stumps of each category with the total number of live and cut stumps in each fragment. Overall, the rate of logging of young trees (DBH 5-10cm) was higher in all forests than the other tree sizes (DBH >11cm). Logging of the young trees was particularly higher in Mtswakara, followed by Gandini and then Mwache. Large trees (Diameter at Breast Height (DBH) >21cm) were least targeted by loggers. Logging of trees of all different categories occurred at a relatively lower rate in Mwache compared to Mtswakara and Gandini (Table 11). The height and diameter of trees in Gandini and Mtswakara was the same but different from those at Mwache. The numbers of dead standing and floor stems of each categories recorded in each forest were very few in each forest. The three forests had few large live (DBH >31cm) trees.

Table 11: *The percentage rate of regeneration and logging of different tree sizes in different forests*

TREE/STUMPS SIZES		TREES/STUMPS	MWA	GAN	MTSW	OVERALL
1	Small trees (5-10cm DBH)	Live trees	52.5	38.8	25.4	27.4
		Cut stumps (dead/alive)	47.5	61.2	74.6	72.6
2	Medium small (11-20cm DBH)	Live trees	75.6	66	53.1	62.9
		Cut stumps (dead/alive)	25.1	34	46.9	37.1
3	Medium large (21-30cm DBH)	Live trees	82.9	75.6	83	79.9
		Cut stumps (dead/alive)	17.1	24.4	17	20.1
4	Large tree (>31cm DBH)	Live trees	84.2	79.7	85.9	83.2
		Cut stumps (dead/alive)	15.8	20.3	14.1	16.8

Legend: MWA-Mwache, GAN-Gandini and MTSW-Mtswakara

4.4 The Conservation Status of the Forest Fragments

4.4.1 Management Structure of Kayas Forests

The Kaya forests (Gandini and Mtswakara) are protected under the Monument and Antiquities Act Cap 215 of 1983, and are under the jurisdictions of the National Museums of Kenya (NMK), managed through the Coastal Forest and Conservation Unit (CFCU) of the sites and monument office of NMK. In July 2008, the Kayas forests in Kenya received international recognition with listing in the World Heritage Sites list. The NMK administration has been managing the Kayas with the assistance from the local people of Mijikenda tribes (Kauma, Chonyi, Jibana, Giriama, Kamabe, Ribe, Rabai, Duruma and Digo) neighbouring these forest, since these communities have historically used them for conducting their traditional ceremonies. In the past and even today Kayas were governed by a council of elders who regulated the extraction of forest resources in the forests. In 2007, a 12 member committee of the council of elders and eight community forest guards managed Kaya Gandini Important Bird Area. The committee was selected by the local Duruma people in collaboration with CFCU-Ukunda and local provincial administration (chief and assistants). Four forest guards resided and operated on the eastern side and the rest patrolled the western part of the forest to ensure the entire forest was fully patrolled. Interviews with local people indicated that there had been no operational committee of the council of elders in Kaya Mtswakara since 2003, but it was resuscitated in January 2007. During the period of the absence of the council, the extraction of forest products by the local people continued without control. When it was constituted in 2007, four local forest guards were also recruited to assist in the patrolling of the Kaya.

In Gandini and Mtswakara, the council of elders as office bearers comprised of the chairman, vice chairman and secretary. Members of the local community approached the chairman of the council when in need of forest products from the Kayas. In these Kayas permission was provided to local people to extract building poles 5-10cm DBH for construction of their houses and collection of firewood. In 2007, to construct a small two-bed roomed traditional hut the locals paid 600 (Ksh.) to the council of elders for a permission to extract the required poles from Kaya Gandini. The levies and fines imposed on culprits arrested in the forest paid for expenditures of conducting communal ceremonies such as the purchase of goat, sheep or cow and castor oils etc. Additionally, in 2007 much of the money had been used in the prosecution processes of people caught illegally poaching trees from the forest without permits from the chairman of the council. The culprits were reported to the chiefs followed by their transportation to Kwale for prosecution if the need arose.

By the end of 2007, out of the eight guards appointed in 2006 to patrol Gandini, only four were actively involved while the other four had completely stopped offering their services. Only two community guards were regularly involved in patrolling Mtswakara out of the four initially appointed. These community forest guards worked on voluntary basis and were not paid for services they provided. Hence, they could discontinue their patrol duties at any given time whenever they were faced with more demanding personal tasks. Some of the community guards had commenced poaching trees from both Kayas instead of protecting the forests as earlier envisioned. In 2007 and 2008, the chairmen of

both Kayas had collected no single cent from community members interested in extracting poles from the Kaya. However, poles cutting was on the rise, and it seemed local people had ceased to recognize the authority of the council of elders. The morale of the majority of the guards and members of the council had gone down badly, and were pessimistic about continuing with their work. Tree poaching and firewood collection using machetes and axes previously prohibited by the council of elders continued without regulation at both Kayas.

The council of elders and the community guards managing the two sacred forests had lost faith in local administration (chiefs and their assistants) which they were supposed to work in co-ordination in order to ensure fines imposed by council of elders were paid. Conflicts of interest in the management of the Kayas between the council of elders and local administration were rampant. In Mtswakara the council of elders had been disbanded and reconstructed by local chief without consulting CFCU office in Ukunda. Additionally, some tree poachers apprehended at Gandini and handed over to the local administration had been released without paying the proscribed fines or any other action being taken against them. The failure of three stakeholders (council of elders, local government administration and NMK-CFCU officials) to collaborate effectively in the prosecution of offenders destroying the Kayas left the guards and elders in a very challenging situation and almost hopeless.

Modernity and the spread of civilization had taken a toll on Duruma culture and traditions. Majority of youths and some old alike were disregarding traditional values of

the Duruma people especially concerning the sacredness of the Kayas. For example, cutting of trees was witnessed right inside the sacred grove at Gandini and Mtswakara. The grove was the most sacred part of a Kaya or the 'holies of holies'. The sacred grove area was clearly marked using a circular trail of about 2m wide cleared off vegetation and easily identified by all community members. It is within this section where traditional ceremonies were conducted by the elders. The grove which was at least 1ha was surrounded by a large buffering area which was accessible to the locals to extract forest resources with permission from the council of elders. However, irrespective of these management challenges, Gandini had a slightly better organised, more committed and co-ordinated council in their protection of the sacred forest than Mtswakara. Overall, the council of elders and their guards seemed extremely passionate about their work of conserving the Kayas and the Duruma traditions.

4.4.2 Extraction of Forest Products by Local People

The three forest sites existed as 'islands' surrounded by people from every side. The Durumas people are principally agriculturalists (maize, cassava, groundnuts) and coconut farmers. They also kept cows and goats. However, with at least 1-5ha per majority of households, animal husbandry was adopting zero-grazing or was completely being phased out to save the small area owned by each household for agriculture. The entire area around Kayas Gandini and Mtswakara was being transformed by agriculture and human settlements into habitats unsuitable to conservation of forest bird species. The Kayas were the main source of building poles to more than 90% of people living 3km around the forests. Selective tree removal included cutting down of young trees (5-10cm

Diameter at Breast Height (DBH) mostly for building purposes and big (>20cm DBH) trees for timber (Appendix 3 and 4). Locals extracted particular trees in Gandini and Mtswakara using hand saws to get timber. The building poles were 5-10 cm DBH and were used for construction of houses which were roofed using dry old coconut leaves (makuti). The Kayas were the main source of firewood used by the local people for cooking who lived 3km around the forest, even though some was sold in the local village towns about 10-20km away (Appendix 3 and 4). The women were permitted by elders to collect only the dead trees, without the use of machetes and axes. However, this rule was always flouted and women carried these tools into the Kayas to use them in removing dead trees which could not be broken using bare hands. Everyday more than 30 people (women and children) entered each of the Kayas to collect firewood. The extraction of poles and firewood for sale in the nearby shopping centres and towns was main reason leading to increasing deterioration of forest habitat at Gandini and Mtswakara.

The Mwache Forest Reserve is located 1km from Mombasa-Nairobi Highway and almost in the middle of two fast growing towns (Mazeras and Miritini), and occurring about 15km from Mombasa City, the second largest city in Kenya (Figure 1). About 60% of the forest neighbouring area was settled by local people and used for settlements and farming activities. Additionally, more than 70% of houses and majority of other household structures in the rural areas and in the nearby towns depended on building poles extracted from Mwache, the nearby mangrove areas and some from the Kayas. The rapid expansion of Mazeras and Miritini was leading to a construction boom of houses to provide accommodation for people working in the nearby city. This resulted into illegal

poaching of young trees from Mwache Forest and mangroves habitat to feed the growing demands of houses. A few big trees were being extracted to make timber for making furniture locally or selling to get some income to support families.

Between 1970s-1990s people were provided permits by Forest Department (now Kenya Forest Service (KFS) to log in the forest. The main trees extracted then included the hardwoods of big trees. However, logging was not allowed at Mwache in 2007-8, but illegal tree poaching was difficult to control because the entire forest area was patrolled by unarmed single forest guard assisted by other two staff (one involved in tree nursery management and the other in supervising quarrying activities). Firewood collection for both household use and sale in the nearby towns was a serious problem at Mwache. Every day more than 50 women with machetes and sometimes axes entered the forest to collect firewood. All dead trees could be broken using this equipment and carried away. Cases of live trees being cut and being carried away as firewood were witnessed. Due to the close proximity of the forest to Miritini, Mazeras and Mombasa the demand for firewood and building poles was very high and much of these resources were sold to customers in these towns.

4.4.3 Human Encroachment into the Forests

Before the Kayas were legally protected through a gazette notice in the early 1990s, some local people had started encroaching into the forests clearing part of these fragments for agriculture and settlements. These local people were forcefully evicted from these forests when Kaya Gandini and Mtswakara were gazetted as National monuments by National

Museum of Kenya in 1992. In 2007-8 the bare and open areas previously habited by people were slowly regenerating with indigenous trees, mixed with cashew nut, coconut, and mango trees left behind by evicted people. In January 2008, there were two families which were living in Gandini. They had houses inside the forest and were farming in the forest annually clearing part of the forest for growing crops. In August 2008, a third family had started initial preparation of moving into the forest, by clearing an area for farming and probably erecting houses. The total area collectively being used by the three families for agriculture and settlements was approximately four hectares. These people were probably involved in continuous extraction of forest products without seeking permission from the council of elders. There were no people living inside Mtswakara and Mwache.

4.4.4 Quarrying

One of the most important conservation issues in Mwache was quarrying (Appendix 4). The forest was replete with rocks, at least twenty meters below the ground, covering about 40% of the forest area. These rocks were very hard to break and suitable for making gravel for roads building construction. In March 2008, four quarries owned by four different companies were operating inside Mwache. These companies were located in the same locality, almost at the centre of the forest, along a marrum road winding through the forest. Before data collection began in October 2007 there were three quarries, but the fourth one was established between October 2007 and January 2008. I estimated that the maximum distant between the farthest and nearest quarry along the marrum road was about 600m. The width of the area covered by the quarries on both side

of the road was estimated to be about 400m, hence making a total of 28ha (700m*400m=28,000m^2/10,000 m^2 (1ha =10,000 m^2). This was an area, completely degraded by clearance of about 80% of indigenous trees and shrubs. Quarrying in Mwache dates back to 1950s when first mines were established by the colonialists. It continued for unknown period of time and stopped and commenced again without cessation in 1992.

The loss of the virgin areas in Mwache through quarrying was not the only conservation problem contributing to loss of biodiversity. Each quarry employed about 20 people, making a total of 80 individuals. Each company had big trucks for transportation of rocks, road graders, caterpillars and ballast graders (Appendix 4: Figure 10 and 11). The machinery produced a lot of noise during the rock extraction process. But the most important of all noise was produced by explosive chemicals used in blasting of big and deep seated rocks. The epicentre of the explosion was very powerful such that its deafening effect could be heard more than five kilometres away. The problem was severe since the stone quarries were relatively located at the centre of the forest.

4.4.5 Community Participation in Conservation of the Forest Sites

The local people neighbouring the three forests dependent on the fragments for the supply of firewood and building poles for household use and for commercial purposes. However, majority of the locals were not involved in any particular activities as individuals or members of a group with an aim of addressing some of the challenges faced by the Kayas or Mwache Forest Reserve. The community guards operating at

Gandini and Mtswakara were involved in day to day conflict with local people illegally poaching forest products from these sites. There were no Community Based Organisations (CBOs) assisting the council of elders, Kenya Forest Service and National Museums of Kenya to conserve any of these forests. However, on 24th July 2008, a CBO known as Mwache Forest Community Conservation Organisation was founded in Mwache Forest Reserve. The group was in the advanced stage of registering the CBO with the government through the Ministry of Social Services in August 2008. The main goal of the CBO was to ensure proper protection of Mwache through re-afforestation (tree planting) of the forest, assistance in the patrolling of the forest reserve including the mangrove forest areas. Mwache forest occupies an area of about 345ha, and had been patrolled by a single KFS forest guard with little success. In August 2008, members of the CBO were patrolling the forest in the morning and evening in groups of at least five people (men and young women included. They assisted the forest guard in Mwache to arrest illegal forest products poachers (Figure 4). This approach had drastically reduced the incidences of illegal tree poaching activities in the reserve. The group however lacked capacity in the following areas; running and management of CBOs, fundraising, tour guiding, bee-keeping, agro-forestry, eco-tourism development activities, birding and starting and running rural based businesses.

Figure 4: *Members of Mwache Forest Community Conservation Organisation arrest a person found illegally extracting building poles in Mwache Forest Reserve (mangrove section) in August 2008.*

4.5 DISCUSSIONS

Kaya Gandini (150ha), Kaya Mtswakara (247 ha) and Mwache Forest Reserve (345 ha) collectively had a total area of 742ha. A total of 141 bird species were recorded in this area. In Arabuko-Sokoke Forest which is the largest (41,600 ha) continuous coastal forest in Kenya, has a total of 230 bird species recorded in it (Fanshawe, 1993; Bennun and Njoroge, 1999). The Arabuko-Sokoke Forest is about 56 times the size of the three forests fragments. Therefore, even though Gandini, Mtswakara and Mwache were very tiny fragments, the species richness in the three sites was high compared to their small size. Additionally, a total of 14 East African Coastal Biome Bird Species (EACBs), which represented 47% of all EACBs recorded in coastal forest biome habitat of Kenya (Bennun and Njoroge, 1999) were recorded. The high species richness and concentration of EACBs in a smaller area, reinforces the biodiversity significance of small coastal forests listed within the Eastern Arc Mountains and coastal forests of Tanzania and Kenya Biodiversity Hotspot (Burgess *et al.*, 2003).

There were more forest specialist birds recorded in Gandini than the other forests. The higher the species richness of specialist birds in a forest the healthier the habitat quality (Bennun and Howel, 2002). This is because the specialist birds require less disturbed habitat section for their survival. The African Crowned Eagle was only recorded in Mwache as a forest specialist. However, the three forests fragments occurred at close proximity to each other, and could be perceived as one single forest block, with almost the same vegetation types and levels of forest destruction, but only divided by river valleys. Therefore, it is most likely that the eagle, a raptor which requires large territories

for its survival (Bennun and Howell, 2002) might be using the three sites for foraging and nesting. Other specialist birds like Black-headed Apalis *Apalis melanocephala* were only recorded in Gandini at the sacred grove. No other records of this species were found away from the grove. Newmark (1991) noted that some forest species might spend their entire lives within a small area, without crossing small gaps between forest patches. These are species which are probably shy and are very sensitive to habitat disturbance.

Waiyaki (1995) recorded seven specialist birds at Gandini and three in Mtswakara. A total of 31 forest species (specialists and generalists) were recorded in Gandini and 23 in Mtswakara (Waiyaki, 1995). The current study recorded eight specialists and 34 forest species in Gandini and four specialists and 25 forest species in Mtswakara. Therefore, over the last 13 years (1995-2008), there were insignificant changes in the numbers of these species in these two fragments. Since birds are relatively good indicators of ecosystems health (Furness and Greenwood, 1993), the stability in the species richness in Mtswakara and Gandini probably, indicate that the habitat condition in the two sites did not undergo serious structural change over the same period. However, a comparison of the densities of the different specialist bird species over the same survey period could be a robust indicator of habitat condition these forests.

Mtswakara and Mwache had the same number of forest species. However, A smaller area of undisturbed (primary habitat) coastal areas (about 90 ha) existed in Gandini but Mwache (about 173ha) and Mtswakara (about124 ha) with much larger area should have been richer in specialist birds or even coastal biome species. Probably, the small and

undisturbed primary habitat of Gandini had factors which favoured the survival of birds than habitat conditions in Mtswakara and Mwache. Overall Gandini, therefore was more important for conservation of avian biodiversity than the other forests.

There were four (Plain-backed Sunbird, Southern Banded Snake Eagle, Fisher's Turaco, Sokoke Pipit) globally threatened birds which were recorded in all forests. Gandini had four species; lacking only the Spotted Ground Thrush which had been recorded in the past (Bennun and Njoroge, 1999; Waiyaki, 1995). This study commenced in late October 2008 and ended in March 2008; and therefore, it was unlikely to record the thrush, since it is an Afro-tropical migrant species which is only recorded in Kenya between April-October annually (Zimmerman, *et al.*, 1996). However, the three fragments seemed very potential sites for the Spotted Ground Thrush because of the large quantities of litter recorded in most of the forests as well the under storey forest thickness (Bennun and Waiyaki (1991).

Previous studies recorded two (Fischer's Turaco and Southern-banded Snake Eagle) Waiyaki, 1995) in Mtswakara. In this survey Southern Banded Snake Eagle was not recorded, but Fischer's Turaco and Plain-backed Sunbird were recorded in this fragment. Southern Banded Snake Eagle and Plain-backed Sunbird were globally threatened species recorded for the first time in Gandini and Mtswakara respectively. Three globally threatened species were recorded in Mwache, which was surveyed for the first time for birds. All other threatened species except Fischer's Turaco were very uncommon, and were heard calling or seen at most once indicating probably that they had low population

sizes. Fischer's Turaco recorded in all sites was more abundant in Gandini where it was seen or heard calling more frequently than in the other sites. The abundance or richness of fruiting plants, for example, is associated with the diversity of frugivorous bird species and their foraging behavior (Moegenburg and Levey, 2003) and habitat choice (Levey, 1988). Therefore, probably, Gandini had more fruiting trees than the other areas in which the turacos could find food (fruits).

In terms of feeding guilds compositions; insectivores (feeding on insects and all other invertebrates by sallying, back gleaning etc) were the most abundant in all forests. (Blake and Loiselle (2001) noted that insectivores are often the most species rich and abundant guild in tropical forests and display considerable variation in feeding behavior. Gandini was richer in insectivores than other two forests. The abundance of some bird feeding guilds may determine the levels of habitat degradation in a forest. For example, insectivores declined after forest disturbance (Gray, *et al.*, (2007). The structural complexity and light regime of the habitat which undergoes considerable change following disturbance, may have important consequences for the search patterns of insectivores (Barlow *et al.*, 2002) or different groups of insectivores, such as bark-gleaners or dead-leaf probers (Rosenberg, 1993). Therefore, habitat disturbance and fragmentation in Mwache and Mtswakara might have led to the decline in abundances of insectivores in these forests. The carnivores, frugivores, granivores, nectarivores and omnivores were represented by few species in each forest and it was difficult to detect a particular pattern. Analysis by Gray, *et al.*, (2007) of feeding guilds composition following habitat disturbance indicated that responses of carnivores, nectarivores, and

omnivores were less clear. However, Gray, *et al.* (2007), noted that differential responses of some guilds suggested that habitat disturbance affects trophic organization and thus ecosystem functioning.

There were no birds ringed in one forest which were recaptured or observed in another forest. This was probably due to the low numbers of individuals of each species banded in each forest, which could not enable higher chances of detection of dispersers among the different fragments. However, it has been noted that tropical under story forest birds are sedentary and avoid gaps (Van Houtan, *et al.*, 2007) and even forest clearing (Pimm *et al.*, 1993). Additionally, Ehrlich and Raven (1969), Willis (1974) Terborgh *et al.* (1990) and Sodhi *et al.* (2004) have noted that some tropical birds do not range widely, do not disperse far from their natal territory and avoid unsuitable habitat due to physical or behavioural limits. Therefore, it would be possible that majority most of the individuals which were banded in one fragment did not disperse into another fragment.

However, this does not completely mean that birds were not moving across the different fragments. Since, the three forests were connected and only separated by physical barriers of rivers and a creek which were not more than 30m wide it was possible that most of the highly mobile species such as Crowned Hornbill, Trumpeter Hornbill, Retz's Helmet Shrike and some other raptor species could disperse and utilise the entire area for different survival needs (Bennun and Howell, 2002). The survival of the birds in these fragments therefore, might heavily depend on the habitat conditions of these forests. This is because even though avian dispersal was not demonstrated, the proximity of fragments

to each other, would possibly allow constant exchanges of highly mobile avifauna across the forests. For example, a bird might forage in one fragment and nest or roost in another where there are suitable resources. Therefore, the three sites should be considered as a single habitat block whose biodiversity might be affected if destructive human activities degrade one or more forest fragments.

About one third of bird species were found occurring in each of the three fragments. This was possible because of the similarity in overall vegetation structure at the three sites. Gandini and Mtswakara had the largest number of similar bird species because the two sites had similar overall vegetation structure. The under storey vegetation densities at 1m and 2m and the lower canopy cover (0-2m) in the three fragments was similar. This situation should have provided at least some similarity in terms of the under storey avifauna species richness and abundance among the three sites. This was not the case because Mwache and Mtswakara were more impoverished of these species than Gandini. The same numbers of under storey birds were caught in Mwache and Mtswakara which were far much lower than the number of individuals caught at Gandini. This probably indicates that there are other factors which should be used to explain for the differences in under storey abundances and species richness among the three sites.

The low numbers of under storey species in Mwache could be as result of quarrying, which was the greatest threat to birds and other biodiversity at that forest. About 28ha (700m*400m=28,000m^2/10,000 m^2 (1ha =10,000 m^2), had been lost at Mwache at a rate of 0.5ha per year for the last 58 years (2008-1950). The loss of habitat for birds through

forest clearance and intense noise produced by chemical explosives, as well as constant collection of firewood and building poles in Mwache by local people could have driven many under storey birds away. Quarrying activities were bound to intensify in future unless urgent measures were undertaken to control them because of high demand for construction materials for roads and houses around Mombasa city and rapidly expanding neighbouring towns (Miritini and Mazeras).

Additionally, Mwache had a very busy murram road which was used to transport rocks and other materials for quarrying activities in the forest. The road cut through the centre of the forest and almost divided Mwache into two blocks, with four quarries located nearly at the centre of the forest on both sides of the road. Fragmentation or division of a continuous habitat using roads, paths, settlements or other human infrastructure has serious negative impacts on survival of animals. Fragmentation for instance affects population density; distribution and species richness (Donovan and Flather, 2002). This is because fragmentation changes the landscape through loss of original habitat via proliferation of human-dominated habitats and division of the original continuous habitat into isolated remnants patches (Pimm *et al.*, 2002). Isolated patches may become far from one another in a way that they become un-reachable by individuals, and thereby lowering the pairing rate (Brooker and Brooker, 2003) of individuals of particular species.

Fragmentation may also affect the availability of critical resources such as food in many ways. Probably the presence of a busy road in Mwache had serious negative effects on the survival of under storey birds. Hence, the variation in the levels of internal

fragmentation and habitat disturbance between Mwache, Mtswakara and Gandini might have resulted into the differences in under storey birds recorded in each site. For instance, Blue-mantled Crested Flycatcher and Red-tailed Ant Thrush were under storey shy birds which were only recorded in Gandini. This probably indicate that the under storey habitat conditions in Gandini was more suitable for the survival of these species than the other forests.

Interestingly, even though Gandini and Mtswakara had similar vegetation structures, they had completely different under storey avifauna, but almost the same canopy bird species. The factors driving the differences in under storey avifauna richness in the two fragments were unclear, but probably the disparity in the logging levels (of different sizes of trees), physical nature and the administrative structure of the two forests could offer some plausible explanation. Kaya Gandini was largely a small hill with one face on the north western side which was rather steep, rising from 10-200m above sea level at the top of the hill. This was the face which was adjacent to large numbers of the locals utilising the forest for firewood and poles. Much of this face representing about 10% of the entire primary habitat area was difficult to access by humans and had remained relatively pristine from destructive human activities. Compared to Mtswakara which had a gentler plane and more easily accessible, Gandini was rather a difficult place to extract forest products because of the difficult terrain. Therefore, Mtswakara could easily be preferred by locals for extraction of forest products at any given time.

The extraction of firewood, building poles and timber for household sale and commercial sale was one of the greatest conservation threats to these forests. There were different levels of logging (removal of live trees evidenced by existence of cut stumps) and regeneration (standing live trees) of different tree sizes in each different forest. Overall, the rate of logging of young trees (Diameter at Breast Height (DBH) 5-10cm) was higher in all forests than the other larger tree sizes (DBH >11cm). This probably was happening because young trees were in high demand for construction purposes of houses in the nearby villages and renting houses in nearby towns such as Miritini, Mazeras and Mombasa City. Additionally, some live trees could easily be extracted and be used as firewood. The high human population surrounding these three fragments continued to extract building poles at an alarming rate. The sizes of these young trees represented the bulk of plants past saplings stage which could support a future healthy forest. Therefore, the indiscriminate removal of these young trees would gradually lead to the impoverishment of forest habitat. Logging of the young trees was particularly higher in Mtswakara, followed by Gandini and then Mwache. This is contrary to what Waiyaki (1995) found that Mtswakara had very little interference from human, because it was the most sacred forest of the Duruma people.

The council of elders responsible for the managing accessibility and the permission for exploitation of forest products in Kaya Mtswakara had not been in operation for the last three years (2003-2006), before it was reconstituted again in 2007. During the absence of the regulating authority, probably Mtswakara had become a 'free for all' resource with influx of people into the forest leading to increasing loss of young live trees for firewood,

building poles and other forest products. Large trees (DBH >21cm) were least targeted by loggers in all forests. The extraction of these trees would require the use of powerful tools (big axes, saws etc). It would also lead to opening of a large canopy gaps when the tree eventually fell down. The difficult of concealing the extraction process of these large trees, given that these fragments were small and surrounded by local communities who used numerous trails to traverse the forests, might have forced loggers to avoid big trees.

Logging of trees of all different sizes occurred at a relatively lower rate in Mwache compared to Mtswakara and Gandini. The differences in logging might have been caused by the existence of different management authorities operating in the Kayas and the forest reserve. The Kayas; were managed by National Museums of Kenya through Coastal Forest Conservation Unit (CFCU) in direct collaboration with Duruma Council of elders. Each Kaya had a council of elders and community forest guards for patrolling the forested Kayas. However, the community forests guards selected by council of elders to police the Kayas were not fully involved in day to day patrolling of the Kaya forests. They only went to patrol the forests when they lacked other pressing duties of their own. Additionally, some of the community guards had turned to poaching of trees from both Kayas, instead of protecting the forests as earlier envisioned. The community forest guards were not paid but worked on voluntary basis, getting tokens of pay whenever the community members extracting forests products paid for permits to extract building poles from the Kayas. The lack of direct economic benefits from the services they offered, poverty and lack of other tangible alternatives for income generating opportunities to

support their families might have possibly forced the guards into tree poaching or to abandon their patrolling duties.

In 2007-8 the council of elders including the community guards (in both Kayas) selected to patrol the forests for illegal activities did not work properly. Some guards had resigned their duties and the council of elders in Mtswakara had been disbanded and reconstituted by the local chiefs without consultation with all stakeholders (CFCU, and local community). This situation probably resulted into massive loss of young trees in Mtswakara. Logging of young trees was still ongoing in Gandini, but at a lower rate than Mtswakara. This is probably was because the council of elders at Gandini was better organised and co-ordinated in their forest patrolling duties. Therefore, the roles of council of elders in the conservation of the Kayas as had been done in the past; even through weakening due to breakdown of traditional ways of life Mijikendas could still be effective in managing these forests if proper assistance was provided by all stakeholders. In 2007-8, even through very few locals were approaching the council of elders in Gandini and Mtswakara for permission to extract forest products, there was increasing loss of trees of different sizes from the Kayas. The locals had ignored the authority of council of elders. On the other hand Mwache was facing minimal logging compared to the Kayas probably because there was a KFS forest guard based at the reserve who was regularly involved in forest patrols and apprehending tree poachers. The assistance of the guard by the upcoming CBO, whose members were involved in regular reserve patrols, was bound to reduce tree poaching significantly.

Overall the three forests were undergoing serious loss of live trees. The three forests also lacked dead standing and floor stems of all sizes, which were targeted by firewood collectors. The removal of the dead wood is detrimental to forest biodiversity, since it affects the density and distribution of cavity nesting bird species due to the decline in quantity of holes and food (invertebrates which they feed on) Waiyaki, 1995).

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The three coastal forests were still very important sites for avifauna conservation. Kaya Gandini was more important for avian conservation because it was richer in forest specialist, generalist, under storey, globally threatened birds and East Africa Coastal Biome Species. Kaya Mtswakara and Mwache Forest Reserve were less rich in under storey species. Firewood collection and extraction of building poles for sale and household uses which were not regulated posed a serious threat to the habitats of the three forest fragments. In Mwache, quarrying by different companies contributed to loss of biodiversity through excessive noise of machinery and explosives including vegetation clearance. The management of Kayas by council of elders was gradually weakening due to dwindling respects and adherence to Duruma cultural traditions by the local people around these forests. The demand for forest products by local people to meet different household and commercial needs was increasing as the population around the Kayas continued to increase, leading to constant clash of community forests guards with illegal tree poachers. Mwache Forest was not well protected because it was patrolled by only one forest guard. Overall, the habitat condition of the three forests was on a declining trend, a situation which could lead to dramatic loss of birds and other existing biodiversity in the near future if not urgently addressed. The listing of the Kayas in the World Heritage Sites list put the Gandini and Mtswakara in the international map and reinforced the importance of these sites for conservation of both biodiversity and Duruma cultural traditions.

5.2 RECOMMENDATIONS

Kayas: Gandini and Mtswakara including Mwache Forest Reserve were facing enormous conservation challenges which required urgent attention in order to secure the future of existing biodiversity. The following interventions were proposed;

1. Due to the proximity of the three forests sites to each other they could be considered as a single forest block whose biodiversity will be affected if the habitat of one or more fragments continues to get degraded by human activities.
2. Improved collaboration among the council of elders, Kenya Forest Service, local provincial administration and National Museums of Kenya-Coastal Forest Conservation Unit (CFCU) to initiate an effective community participatory forest conservation in the three forests.
3. All stakeholders involved in the conservation of Kayas; Gandini and Mtswakara need to work out modalities for remuneration of the community forest guards.
4. Strengthen the capacity of the local people to actively participate in addressing environmental problems in and outside the forests through formation of Community Based Organisations (CBOs).
5. Mobilise members of community living around the forests to replant degraded areas of the three forests with indigenous trees and also be encouraged to plant trees around their homes (woodlots) to act as source of firewood for cooking.
6. More extension services on agricultural and forestry issues are needed to increase food productivity and maximisation of yields and reduce pressure on extraction of forests products for sale.

7. Improved enforcement of different legislation on environment such as Forests Act 2005, Government Lands Act (Cap. 280), the Water Act (Cap. 372), Wildlife Conservation and Management Act (as amended in 1989) and Environmental Management and Co-ordination Act (EMCA) 1999 among others by various government institutions in order to save these forests.
8. Market the sacred forests (Gandini and Mtswakara) as tourist destinations through exhibition of Duruma cultures and traditions by drawing on Mombasa City as focal point of tourists and the listing of Kayas as World Heritage Sites.

ADDITIONAL RESEARCH: Further is research is required to provide missing scientific information to enhance effective conservation of the forest habitats and existing biodiversity as well addressing the welfare of the local people living adjacent to these fragments which includes;

a) The economic value of eco-tourism should be determined in Mwache Forest Reserve and compare it with earnings from the quarrying activities.
b) Investigate avifauna composition in the wet season and dry season regularly throughout the year.
c) Determine the amount of poles, timber and fuel wood extracted from these sites and its final destination in order to understand the rate at which the forests are getting depleted for local and commercial uses.

d) Produce an updated checklist of other taxonomic groups such as mammals, reptiles and amphibians and invertebrates; and determine whether the forests hold populations of coastal endemics or globally threatened species.

e) Investigate and advice about alternative sources of energy and building materials for household (eg solar or energy saving Jikos etc) use to reduce dependence on extraction of forest products.

9. Conduct Environmental Impact Assessment and audits before and after quarrying projects are initiated at Mwache Forest Reserve. This information will provide important insights into the actual effects of quarrying activities to biodiversity.

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APPENDICES

Appendix 1: *List of bird species recorded in the three sites* (see legend for initials used)

	List of Bird Species	Habitat	Fragment	FBC	Status
1	African Barred Owlet *Glaucidium capense schemperi*	P,s	G,MTSW,MWA	F	c
2	African Crowned Eagle *Stephanoaetus coronatus*	p	MWA	FF	r
3	African Goshawk *Accipiter tachiro*	P,s	G, MTSW , MWA	F	a
4	African Green Pigeon *Treron calva gibberifrons*	f	G	F	r
5	African Harrier Hawk *Polyboroides t. typus*	P, HCAs	G, MTSW	f	c
6	African Palm Swift *Cypsiurus parvus laemostigma*	f	G, MTSW	NFB	a
7	African Paradise Flycatcher *Terpsiphone viridis*	P,s	MWA,G	f	c
8	African Wood Owl *Strix woodfordii nigricatior*	P,s	G, MTSW , MWA	F	c
9	Amethyst Sunbird *Nectarinia amethystine*	s	G, MTSW , MWA	f	c
10	Ashy Flycatcher *Muscicapa caerulescens cinereola*	P,s	G, MTSW , MWA	F	c
11	Barn Owl *Tyto alba affinis*	p	MWA	NFB	r
12	Barn Swallow *Hirundo rustica*	S,HCAs	G, MTSW	NFB	a
13	Black and White Mannikin *Lonchura bicolor*	S,HCAs	MWA	f	c
14	Black Kite *Milvus migrans parasitus*	P,HCAs	MTSW, G	NFB	c
15	Black-backed Puffback *Dryoscopus cubla*	P, S, HCAs	MWA, G	F	c
16	Black-bellied Starling *Lamprotornis corruscus mandanus*	P,s	G, MTSW , MWA	F	a
17	Black-chested Snake Eagle *Circaetus pectoralis*	S,HCAs	MWA	NFB	r
18	Black-crowned Tchagra *Tchagra s. senegala*	S,HCAs	MTSW, G , MWA	NFB	c
19	Black-cuckoo Shrike *Campephaga flava*	S,HCAs	G, MTSW	f	c
20	Black-headed Apalis *Apalis melanocephala*	p	G	FF	r
21	Black-headed Batis *Batis minor*	s	MWA	NFB	r
22	Black-headed Heron *Ardea melanocephala*	MBr,mr	G,MTSW	NFB	c
23	Black-headed Oriole *Oriolus larvatus rolleti*	P,s, HCAs	G	NFB	r
24	Black-headed Weaver *Ploceus cucullatus*	HCAs	G	f	r
25	Black-throated Wattle-eye *Platysteira p. peltata*	s	G	F	r
26	Blue-mantled Crested Flycatcher *Trochocercus cyanomelas bivittatus*	p	G	FF	vr
27	Bohm's Spinetail *Neafrapus boehmi sheppardi*	f	G, MTSW	F	c
28	Broad-billed Roller *Eurystomus glaucurus suahelicus*	P, HCAs	G	f	r
29	Bronze Mannikin *Lonchura cucullatus scutata*	Mr,HCAs	MTSW, MWA	NFB	c
30	Brown Snake Eagle *Circaetus cinereus*	S, HCAs	MTSW, G	NFB	r
31	Brown-breasted Barbet *Lybius melanopterus*	p	G,MTSW	f	r
32	Brown-headed Parrot *Poicephalus cryptoxanthus*	S, HCAs, p	G, MTSW , MWA	F	c
33	Brown-hooded Kingfisher *Halcyon albiventris orientalis*	S,MBr	MTSW,G	NFB	c
34	Carmine Bee-eater *Merops nubicus*	S,HCAs	MTSW, MWA	NFB	c
35	Chestnut-fronted Helmet-shrike *Prionops scopifrons kirki*	s	G	F	vr
36	Collared Sunbird *Anthreptes collaris garguensis*	P,s	G, MTSW , MWA	F	c

	List of Bird Species	Habitat	Fragment	FBC	Status
37	Common Bulbul *Pycnonotus barbatus*	S,HCAs	G, MTSW	f	c
38	Common Drongo *Dicrurus adsimilis*	P,s,HCAs	G, MTSW , MWA	f	c
39	Common Greenshank *Tringa nebularia*	mc	MWA	NFB	r
40	Common Sandpiper *Actitis hypoleucos*	Mc, mr	MTSW, MWA	NFB	r
41	Common Waxbill *Estrilda astrild*	s	MWA	NFB	r
42	Coqui Francolin *Francolinus coqui*	s	MTSW, MWA	NFB	c
43	Crested Francolin *Francolinus sephaena*	S, HCAs	MTSW, MWA	NFB	c
44	Crested Guineafowl *Guttera pucherani*	p	G, MTSW , MWA	F	c
45	Crowned Hornbill *Tockus alboterminatus geloensis*	P,s	G, MTSW , MWA	f	a
46	Eastern Bearded Scrub Robin *Cercotrichas q. quadrivirgata*	p, s	G, MTSW , MWA	f	a
47	Eastern Nicator *Nicator gularis*	P,s	G, MTSW , MWA	F	a
48	Emerald Spotted Wood Dove *Turtur chalcospilos*	S,HCAs	MTSW, MWA,G	f	a
49	Eurasian Bee-eater *Merops apiaster*	S, HCAs	G, MTSW	f	c
50	Eurasian Golden Oriole *Oriolus o. oriolus*	p,s, HCAs	MTSW, MWA,G	f	c
51	Eurasian Honey Buzzard *Pernis apivorus*	s,HCAs	MTSW	F	vr
52	Eurasian Roller *Coracias garrulus*	p,s	MTSW , MWA	NFB	c
53	Fiery-necked Nightjar *Caprimulgus pectoralis*	P,s	G, MTSW , MWA	F	r
54	Fischer's Greenbul *Phyllastrephus fischeri*	P,s	G, MTSW	FF	r
55	Fischer's Turaco *Tauraco fischeri*	P,s	G, MTSW, MWA	F	r
56	Flappet Lark *Mirafra rufocinnamomea*	HCA,s	G, MWA	NFB	c
57	Forbe-watson's Swift *Apus berliozi bensoni*	f	MTSW	NFB	r
58	Great Egret *Casmerodius albus*	mc	MWA	NFB	r
59	Great Sparrowhawk *Accipiter melanoleucus*	P,s	G, MTSW , MWA	F	c
60	Greater Blue-eared Starling *Lamprotornis chalybaeus*	s	MTSW	NFB	r
61	Greater Honeyguide *Indicator indicator*	S, HCAs	G	NFB	r
62	Green Wood Hoopoe *Phoeniculus purpureus*	P,s	G, MTSW , MWA	NFB	c
63	Green-backed Twinspot *Mandingoa nitidula chubbi*	P,s	G,MWA	FF	c
64	Grey-backed Cameroptera *Camaroptera brevicaudata*	P,s	G, MTSW , MWA	f	c
65	Grey-headed Bush-shrike *Malaconotus blanchoti approximans*	p	MTSW	NFB	r
66	Grey-headed Kingfisher *Halacyon leucocephala*	p,s	G, MWA,MTSW	NFB	r
67	Grosbeak Weaver *Amblyospiza albifrons*	mr	MTSW	f	r
68	Hadada Ibis *Bostrychia hagedash*	MBr, mc	G, MTSW , MWA	NFB	c
69	Hamerkop *Scopus umbretta*	MBr,mr,mc	G, MTSW	NFB	c
70	Harlequin Quail *Coturnix delegorguei*	s	MWA	NFB	r
71	Hooded Vulture *Necrosyrtes monachus*	p	G	f	r
72	House Crow *Corvus splendens*	S, HCAs	MWA, G	NFB	c
73	Lesser Masked Weaver *Ploceus intermedius*	s	MWA	NFB	r
74	Lesser Stripped Swallow *Hirundo abyssinica unitatis*	HCAs,f	G	NFB	c
75	Lilac-breasted Roller *Coracias caudate*	HCAs	MTSW, G	NFB	c
76	Little Sparrowhawk *Accipiter minullus*	P,s	G, MTSW , MWA	f	c

	List of Bird Species	Habitat	Fragment	FBC	Status
77	Little Stint *Calidris minuta*	mc	MWA	NFB	r
78	Little Swift *Apus affinis*	p	MTSW , MWA	NFB	c
79	Lizard Buzzard *Kaupifalco monogrammicus*	s	G, MTSW , MWA	f	c
80	Long-crested Eagle *Lophaetus occipitalis*	P, HCAs	G, MTSW	f	r
81	Long-tailed Fiscal *Lanius cabanisi*	HCAs	MWA	NFB	c
82	Madagascar Bee-eater *Merops superciliosus*	HCAs	G	NFB	r
83	Malachite Kingfisher *Alcedo cristata*	mr	MTSW	NFB	r
84	Marsh Sandpiper *Tringa stagnatilis*	Mc,mr	MWA, MTSW	NFB	r
85	Martial Eagle *Polemaetus bellicosus*	p	MTSW, MWA	NFB	vr
86	Mombasa Woodpecker *Campethera mombassica*	P,s	G, MTSW , MWA	F	c
87	Mottled Spinetail *Telacanthura ussheri*	f	MTSW, MWA	F	c
88	Mouse-coloured Sunbird *Nectarinia veroxii*	s	MWA	f	vr
89	Narina Trogon *Apaloderma narina*	P,s	G, MWA	F	c
90	Northern Brownbul *Phyllastrephus strepitans*	s	MWA,MTSW	f	c
91	Olive Sunbird *Nectarinia olivacea*	p	G, MTSW , MWA	FF	c
92	Pale Flycatcher *Bradornis caerulenscens cinereola*	s	G, MWA	NFB	c
93	Palmnut Vulture *Gypohierax angolensis*	f	G	NFB	r
94	Pangani Longclaw *Macronyx aurantiigula*	P,s	G, MWA	NFB	r
95	Parrot-billed Sparrow *Passer g. gongonensis*	HCAs	MTSW	NFB	r
96	Pied Crow *Corvus albus*	P,HCAs	MTSW, MWA	NFB	c
97	Pied Kingfisher *Ceryle rudis*	MBr,mr	G, MTSW	NFB	c
98	Pin-tailed Whydah *Vidua macroura*	HCAs	G	NFB	r
99	Plain-backed Sunbird *Anthreptes reichenowi*	p	G, MTSW , MWA	FF	r
100	Purple Grenadier *Uraeginthus ianthinogaster*	HCAs	G	NFB	r
101	Rattling Cisticola *Cisticola chiniana*	HCAs	MWA	NFB	c
102	Red-capped Robin-chat *Cossypha natalensis*	p	G, MTSW, MWA	F	c
103	Red-cheeked Cordon Bleu *Uraeginthus bengalus*	s	MTSW,G	NFB	c
104	Red-eyed Dove *Streptopelia semitorquata*	P,s	MTSW, MWA	f	c
105	Red-fronted Tinkerbird *Pogoniulus pusillus*	P,s	G, MWA, MTSW	NFB	a
106	Red-tailed Ant Thrush *Neocossyphus rufus*	p	G	FF	r
107	Retz's Helmet Shrike *Prionops retzii*	P,s	G, MTSW , MWA	F	a
108	Ringed plover *Charadrius hiaticula*	Mc, MBr	MTSW, MWA	NFB	r
109	Ring-necked Dove *Streptopelia capicola somalica*	HCAs,s	G,MTSW,MWA	f	c
110	Scaly Babbler *Turdoides aylmeri kenianus*	s	MWA	NFB	vr
111	Scaly-throated Honeyguide *Indicator variegatus*	p	MWA	f	vr
112	Senegal Plover *Vanellus lugubris*	p	G	NFB	vr
113	Siffling Cisticola *Cisticola brachypterus*	S,HCAs	MWA	NFB	r
114	Slender-billed Nightjah *Camprimulgus clarus apatelius*	s	G, MTSW , MWA	NFB	c
115	Sokoke Pipit *Anthus sokokensis*	f	G, MWA	FF	vr
116	Southern Banded Snake Eagle *Circaetus fasciolatus*	f	G	F	vr

	List of Bird Species	Habitat	Fragment	FBC	Status
117	Southern Ground Hornbil *Burcovus abyssinicus*	HCAs	MTSW	NFB	r
118	Spotted Flycatcher *Muscicapa striata*	S,HCAs	G, MWA	NFB	c
119	Spotted Morning Thrush *Cichladusa guttata*	p	G	NFB	r
120	Stripped Kingfisher *Halcyon c. chelicuti*	s	MTSW	NFB	r
121	Tambourine Dove *Turtur tympanistria*	P,s	G, MWA	F	c
122	Three-banded Plover *Charadrius tricollaris*	mc	MWA	NFB	r
123	Tropical Boubou *Laniarius aethiopicus*	s	G, MTSW , MWA	f	a
124	Trumpeter Hornbill *Bycanistes bucinator*	P,s	G, MTSW , MWA	F	c
125	Verreaux's Eagle Owl *Bubo lacteus*	P,s	MTSW	F	r
126	Von-der Deckens Hornbill *Tockus deckeni*	p	MTSW	NFB	r
127	Wahlberg's Eagle *Aquila wahlbergi*	f	G	NFB	r
128	Water Thick-knee *Burhunis v. vermiculatus*	MBr, mr,mc	G,MTSW,MWA	NFB	r
129	White-browed Coucal *Centropus superciliosus*	s	G, MTSW , MWA	NFB	c
130	White-throated Bee-eater *Merops albicollis*	P,s,HCAs	MTSW, MWA	NFB	c
131	Wholly-necked Stork *Ciconia episcopus*	mc	G, MTSW , MWA	NFB	r
132	Winding Cisticola *Cisticola galactotes*	mc	MWA	NFB	r
133	Wire-tailed Swallow *Hirundo smithii*	Mc,mr	MWA,MTSW	NFB	c
134	Wood Sandpiper *Tringa glareola*	Mc,MBr	MTSW, MWA	NFB	r
135	Yellow-bellied Greenbul *Chlorocichla flaviventris*	s	G, MTSW , MWA	F	c
136	Yellowbill *Ceuthmochares a. aereus*	P,s	G,MWA	F	c
137	Yellow-billed Egret *Mesophoyx intermedia brachyrhyncha*	mc	MWA	NFB	r
138	Yellow-fronted Canary *Serinus mozambicus*	HCAs,s	G, MTSW , MWA	NFB	c
139	Yellow-throated Longclaw *Macronyx c. croceus*	HCAs, s	G, MTSW , MWA	NFB	c
140	Zanzibar Red Bishop *Euplectes ningroventris*	HCAs	MWA	NFB	r
141	Zanzibar Sombre Greenbul *Andropadus importunus*	s	G, MTSW , MWA	NFB	c

Legend: (**G**-Kaya Gandini, **MTSW**-Kaya Mtswakara, **MWA**- Mwache Forest Reserve, **P**-Primary habitat, **s**-secondary habitat, **HCAs**-habited and cultivated areas, **MBr**-Mbome River, **Mr**-Mwache River, **Mc**-Mwache Creek, **FF**-Forest Specialist, **F**-Forest generalist, **f**-Forest visitor, **NFB**-Non forest bird, **FBC**-Forest Bird category). *Status*: **c**-common, **r**-rare, **a**-abundance, **vr**-very rare.

Appendix 2: *Relative abundances of bird species recorded in the three forest fragments* (see legend for initials used).

	List of species	Gandini	Mtswakara	Mwache	Forest Category
1	African Crowned Eagle *Stephanoaetus coronatus*	0	0	2.14	Spe
2	African Goshawk *Accipiter tachiro*	2.95	2.18	2.18	Gen
3	African Harrier Hawk *Polyboroides t. typus*	2.14	0	0	Vis
4	African Palm Swift *Cypsiurus parvus laemostigma*	2.68	2.59	0	NFB
5	African Paradise Flycatcher *Terpsiphone viridis*	0	0	2.05	Vis
6	African Wood Owl *Strix woodfordii nigricatior*	2.09	2.09	0	Gen
7	Amethyst Sunbird *Nectarinia amethystina*	2.14	2.23	0	Vis
8	Ashy Flycatcher *Muscicapa caerulescens cinereola*	2.23	2.18	0	Gen
9	Barn Swallow *Hirundo rustica*	2.64	2.45	0	NFB
10	Black-backed Puffback *Dryoscopus cubla*	0	0	2.18	Gen
11	Black-headed Apalis *Apalis melanocephala*	2.73	2.14	0	Spe
12	Brown-headed Parrot *Poicephalus cryptoxanthus*	2.05	0	0	Gen
13	Carmine Bee-eater *Merops nubicus*	0	2.09	2.5	NFB
14	Collared Sunbird *Anthreptes collaris garguensis*	2.55	2.95	2.64	Gen
15	Common Drongo *Dicrurus adsimilis*	2.18	2.23	2.09	NFB
16	Crested Francolin *Francolinus sephaena*	0	0	2.18	Gen
17	Crowned Hornbill *Tockus alboterminatus geloensis*	2.41	2.5	2.36	Vis
18	Eastern Bearded Scrub Robin *Cercotrichas q. quadrivirgata*	3.68	3.64	4.05	Vis
19	Eastern Nicator *Nicator gularis*	3.09	3.05	2.73	Gen
20	Emerald Spotted Wood Dove *Turtur chalcospilos*	0	2.09	2.41	Vis
21	Eurasian Bee-eater *Merops apiaster*	2.23	2.59	0	NFB
22	Eurasian Golden Oriole *Oriolus o. oriolus*	2.23	2.55	0	Vis
23	Eurasian Honey Buzzard *Pernis apivorus*	0	2.27	0	NFB
24	Fiery-necked Nightjar *Caprimulgus pectoralis*	0	2.09	2.36	Gen
25	Fischer's Greenbul *Phyllastrephus fischeri*	2.45	2.36	0	Spe
26	Fischer's Turaco *Tauraco fischeri*	2.23	0	0	Gen
27	Great Sparrowhawk *Accipiter melanoleucus*	2.09	2.05	2.14	Gen
28	Green Wood Hoopoe *Phoeniculus purpureus*	0	2.05	0	NFB
29	Grey-backed Cameroptera *Camaroptera brevicaudata*	3.73	3.27	2.59	Vis
30	Little Sparrowhawk *Accipiter minullus*	2.05	2.18	0	Vis
31	Little Swift *Apus affinis*	0	2.18	2.18	NFB
32	Martial Eagle *Polemaetus bellicosus*	0	2.05	0	NFB
33	Mombasa Woodpecker *Campethera mombassica*	2.36	2.18	2.27	Gen
34	Mottled Spinetail *Telacanthura ussheri*	0	2.18	0	Gen
35	Northern Brownbul *Phyllastrephus strepitans*	0	0	2.05	Vis
36	Olive Sunbird *Nectarinia olivacea*	3	3.45	2.64	Spe
37	Plain-backed Sunbird *Anthreptes reichenowi*	0	2.05	2.18	Spe
38	Red-eyed Dove *Streptopelia semitorquata*	0	2.32	0	Vis
39	Red-fronted Tinkerbird *Pogoniulus pusillus*	0	0	2.55	NFB
40	Red-tailed Ant Thrush *Neocossyphus rufus*	2.18	0	0	Spe
41	Retz's Helmet Shrike *Prionops retzii*	3.14	2.82	2.18	Vis
42	Scaly-throated Honeyguide *Indicator variegatus*	0	0	2.18	Vis
43	Senegal Plover *Vanellus lugubris*	2.27	0	0	NFB
44	Tambourine Dove *Turtur tympanistria*	0	0	2.14	Gen
45	Tropical Boubou *Laniarius aethiopicus*	2.59	2.23	2.18	Vis
46	Trumpeter Hornbill *Bycanistes bucinator*	2.55	0	0	Gen
47	White-browed Coucal *Centropus superciliosus*	0	0	2.14	NFB
48	White-throated Bee-eater *Merops albicollis*	2.23	2.18	0	Vis
49	Yellow-bellied Greenbul *Chlorocichla flaviventris*	2.73	2.32	2.23	Gen

Legend: Vis-visitor, **Spe**-specialist, **Gen**-generalist, **NFB**-non-forest bird

Appendix 3: *Photo galleries of logging in the forest fragments*

Figure1: Poles used to build houses in all forest fragments

Photos 2: Poles abandoned in the forests by fleeing poachers

Figure 3: Poles cut for timber extraction from all forests

Figure 4: Poles extracted illegally by people in all forests

Figure 5: Poles at Gandini village from Kaya Gandini

Figure 6: Cut poles from all forest fragments

Appendix 4: *Photo galleries of logging in the forests and quarrying in Mwache Forest*

Figure 7: logging for timber (pitsawing)-in all forests

Figure 8: Firewood collectors (with pangas)-in all forests

Figure 9: Women the main collectors of firewood in all forests

Figure 10: Quarrying at Mwache Forest

Figure 11 Quarrying at Mwache Forest

Figure 12: Degraded areas around all forest fragments

Appendix 5: *Photo galleries of birds caught and ringed in study areas*

Photo 1: Collared Sunbird-All sites

Figure 4: Red-tailed Ant Thrush-Gandini

Photo 2: Eastern-bearded Scrub Robin-all sites

Photo 5: African Goshawk-Gandini

Photo 3: Hooded Vulture (Gandini)

Figure 6: Yellow-bellied Greenbul-Gandini