**OCEAN LIFE**
Volume 1, Number 2, December 2017 E-ISSN: 2580-4529
Pages: 69-83 DOI: 10.13057/oceanlife/o010205

# The abundance of bird species in three sections of Kwale District's coastal forests in Kenya

**SIMON NGANDA MUSILA[1], SAYAM MANOHAR[1], NELSON MANGO[2,♥]**
[1]Department of Environmental Studies, Kenyatta University. Nairobi, Kenya
[2]Department of Agricultural Science and Technology, Kenyatta University. Nairobi, Kenya. Tel.: +254-20-8710910, ♥email: nelsonmango16@gmail.com

Manuscript received: 9 September 2017. Revision accepted: 29 December 2017.

**Abstract.** *Musila SN, Manohar S, Mango N. 2017. The abundance of bird species in three sections of Kwale District's coastal forests in Kenya. Ocean Life 1: 69-83.* Specifically, the diversity of bird species in the three coastal forests of *Kaya* Gandini Important Bird Area, *Kaya* Mtswakara, and Mwache Forest Reserve, Kenya, was studied between October 2007 and August 2008. To survey the understory birds of each forest, three ringing stations separated by 200-500 m and two net lines (60 m (18m x 2, 12m x 2)) and (54m (18m x 3)) separated by 60 m were utilized. Twenty-two Timed Species Counts (TSCs) were conducted in the treetops of each forest to determine the bird population. 10 $m^2$ plots were established at 50-meter intervals around the ringing locations and TSCs survey routes, with the plot centers 10 meters perpendicular to the paths. One hundred forty-one different bird species were documented across all locations; 93 were found in Gandini, 88 in Mtswakara, and 91 in Mwache. Common to all three sections were 41 bird species types (29%), accounting for 44%, 47%, and 45% of all bird species documented in Gandini, Mwache, and Mtswakara, respectively. Overall, 38 species of forest birds were registered across all forests, including 34 in Gandini and 25 in both Mtswakara and Mwache. Four globally endangered bird species and 14 endemics to the East African Coastal Biome were discovered across all forest types. There were no migrating birds in any of the three areas, even though they were all a part of the same forest. Although Gandini and Mtswakara were the most similar, all three locations shared a similar habitat structure. Bird populations in Mwache were affected by human activities such as firewood collecting, extraction of building poles (5-10 cm DBH) for domestic and commercial use, and quarrying. Gandini stands out as the most crucial location for avifauna conservation due to its greater diversity of Forest Specialist (FF), Forest Generalist (F), understory, globally threatened birds and EACB species. Due to their close vicinity and the significant number of overlapping forest birds and internationally vulnerable bird species, all three forests should be conserved or maintained as a single forest block to ensure the survival of the greatest possible number of bird species.

**Keywords:** Biodiversity, birds, fragments, Forests, habitat, *Kaya*s, species

## INTRODUCTION

Kenya's coastal forests used to be one continuous ecosystem that extended from Lamu north to Lungalunga south. These forests are found amid a fast-growing human population but are only visible as small, scattered patches of forest (Bennun and Njoroge 1999; Musila et al. 2005). Wood carving, firewood gathering, charcoal burning, timber and pole extraction, encroachment for settlement and agriculture, and other human development activities continue to pose the greatest risks (Hamilton 1981; Howell 1981; Burgess et al. 2003; Adhikerana and Sugardjito 2010). Even though these forests are crucial for biodiversity (most of the coastal forests and the Eastern Arc Mountains in Kenya and Tanzania are listed in the Eastern Arc Mountains and Coastal Forest Biodiversity Hotspot), they are deteriorating as human population increases. Small indigenous forests (*kaya*), such as *Kaya*s Gandini (150 ha), Mtswakara (247 ha), and Mwache Forest Reserve (c. 345 ha) (Bennun and Njoroge 1999), are all documented inside this hotspot (Burgess et al. 2003). There has been a call for the Critical Ecosystem Partnership Fund (CEPF) to prioritize the restoration and improvement of connection across Gapehtee forest sections across the hotspot based on sound biological research (Burgess et al. 2003). Some species in the biodiversity hotspot are little understood, while others are in immediate danger due to a lack of information (Burgess et al. 2003). In addition to the Sookoke Pipit (*Anthus sokokensis*), Plain-backed Sunbird (*Anthreptes reichenowi*), Fischer's Turaco (*Turaco fischeri*), and Spotted Ground Thrush (*Zoothera guttata fischeri*), *Kaya* Gandini is home to two more globally endangered bird species (Bennun and Njoroge 1999).

Previous studies in *Kaya* Mtswakara revealed that similar to that of *Kaya* Gandini, its avifauna was less diversified and lacked two endangered species (Waiyaki 1995). No avian surveys have been undertaken in Mwache Forest Reserve. Furthermore, surveys were necessary to determine the condition of these species in Gandini and Mtswakara to determine if any of the threatened birds occurred in Mwache Forest Reserve. It could result in both woodland fragments and Gandini being designated as a single Important Bird Area (IBA) (Bennun and Njoroge 1999). The most efficient method of connecting the three forest patches might be determined using the extra scientificReena on the bird community.

*Kaya* Gandini, *Kaya* Mtswakara, and Mwache Forest Reserve were likely formerly one large forest that was cut up by human population development and related activities. Settlements, logging, firewood collection, game hunting,

and the collection of other forest resources all contribute to the degradation and alteration of the habitats inside the forest patches. Four species of birds considered globally threatened have been spotted in *Kaya* Gandini (Bennun and Njoroge 1999), with a further two spotted in *Kaya* Mtswakara. Since the 1999 publication of the Important Bird Areas (IBA) Directory, neither *Kaya* Gandini norMtswakara have been the subject of any bird surveys. Mwache Forest Reserve has never conducted a bird survey (Bennun and Njoroge 1999). Surprisingly distinct groups of flora and fauna have been demonstrated to exist in various coastal forests, even when adjacent (Burgess et al. 2003). Since so little was known about *Kaya* Mtswakara and Mwache Forest Reserve, it was crucial to learn more about them in the future (Bennun and Njoroge 1999; Burgess et al. 2003). Species typical of the East African Coastal Biome Bird Species (EACBs) were probably found there. As a result, human activities have likely negatively impacted the bird populations in these areas, particularly forest-specialized species (including globally threatened ones). It seemed likely that animals would travel between fragments in search of food, mates, and territory due to the close closeness of the patches.

The research objective was to: (i) Learn more about the diversity of bird species in the three different types of fragmented forests. (ii) Figuring out the distribution of birds between the three forest sections. (iii) Figuring out the consequences of habitat deterioration on the diversity of bird species. (iv) Compiling a list of the endangered and coastal biome bird species. (v) Identifying the dangers facing the three coastal forests.

## MATERIALS AND METHODS

### Study area and characteristics

*Kaya* Gandini (150 ha), *Kaya* Mtswakara (247 ha), and Mwache Forest Reserve (345 ha) are the three coastal forest locations in Kwale District (Kasemeni Division), Southern Kenya, where this study was carried out. Located at 04°01°S, 39°30'E, at an elevation of 140-200 m above sea level, they are roughly 15 kilometers from Mombasa (Figure 1). All of these locations are part of the Eastern Arc and Coastal (Kenya and Tanzania) Forests Biodiversity Hotspot (Burgess et al. 2003), and *Kaya* Gandini is a designated Important Bird Area (IBA). In addition, they are located close to one another, with the Mbome/Gandini River separating the Gandini and Mtswakara *Kaya*s and the Mwache River and Mwache Creek connecting the Mtswakara and Mwache Forest Reserve.

*Soils*

Significant tectonic activity, sedimentation, and erosion linked with shoreline displacement have all left their geological mark on the coastal forest strip (Burgess and Clarke, 2000). Soils of *Kaya* Gandini and Mtswakara are composed of Duruma/Kambe sandstone (Waiyaki 1995). The soil at the three locations is distinctive, even within a single sample. The eastern portion of the Mwache forest is characterized by its black soils, while the western part is characterized by its loamy soils and a high percentage of litter cover. Forty-five percent of *Kaya* Mtswakara is made up of Duruma/Kambe sandstone, which results in red grounds that eventually extend to the surrounding areas. Thirty percent of the trees here are *Kaya* Gandini. Approximately half of the fragment in *Kaya* Gandini has extensive vegetation cover, presumably influenced by the breakdown of litter found in the other sixty percent. Sites with sandy soils drain well.

*Rainfall*

This region experiences two distinct types of precipitation: light rain from October to December and heavy rain from March to July. On average, 400 and 1,200 millimeters of rainfall annually (Ityeng et al. 2008). Axelrod and Raven (1978) found that while climate had been relatively consistent in the past, it had recently undergone significant swings from year to year, most likely driven by the current consequences of climate change, which have resulted in frequent and unexpected droughts and floods. This study was carried out during the dry months of 2007-2008, from late October to early March. A quick survey of nocturnal birds was conducted between 17 August 2008 and 26 August 2008, at the start of a brief dry period following the end of the long rains.

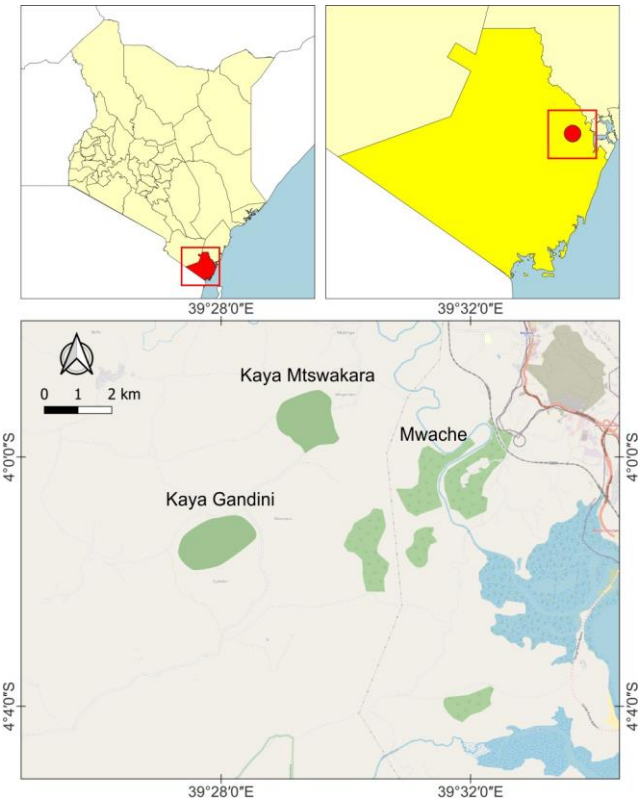


**Figure 1.** Map of Kenya showing the locations of the three study areas as indicated by the arrows

*Temperature and winds*

The average temperature was 27.4°C, with the low being 22.9°C and the high being 32.1°C. Since the research regions were next to the humid waters of the Indian Ocean, the average relative humidity was relatively high, at 75.1%. In addition, on average at 13.7 km/h, strong winds often blew across the research regions due to the significant variations in sea level (TuTiempo.net 2008).

*Vegetation*

The Cynometra-Terminalia dry deciduous forest community was represented by the plants in three separate forest areas (Robertson and Luke 1993). According to Robertson and Luke's (1993) records, none of the three location features stands of a distinct dominant vegetation type characterized by one or more tree species. Instead, the vegetation at these locations is a mix of species like *Brachystegia spiciformis*, *Cynometra webberi*, *Afzelia quanzensis*, and others. In addition, Baobab trees (*Adansonia digitata*) were scarce in Mwache Forest Reserve but were found in small numbers in *Kaya*s, Gandini, and Mtswakara, primarily near the sacred forests.

*Other animals*

Aside from a few small mammals and primates, no large creatures were spotted in the three forests. However, traces of their presence were mostly in burrows. Evidence of the Four-toed Elephant-Shrew, *Petrodromus tetradactylus*, has been found in *Kaya* Gandini. The vervet monkey (*Cercopithecus aethiops*), the blue monkey (*Cercopithecus mitis*), and the Angolan black and white colobus monkey (*Colobus angolensis*) are all examples of palliative species. There were more Black and White Colobus monkeys in Gandini than in Mwache or Mtswakara. The Bush Pig (*Potamochoerus larvatus*) and the Aardvark (*Orycteropus afer*) were two more large creatures that were spotted. The Mwache Forest Reserve is home to the suni Neotragus moschatus. The following species have been involved in conflicts with humans: Bush Pigs were feasting on cassavas and groundnuts as the Vervet Monkey, and Olive Baboon (*Papio anubis*) destroyed ripe maize. The locals, especially those close to the forests, either spent much time at night and during the day securing their crops, avoided growing certain crops or just gave up farming altogether. Not all invertebrates (insects, spiders, molluscs, etc.), reptiles, and amphibians at these locations could be pinned down to a specific species.

*Socio-economic issues*

People's who made their homes near woodlands engaged in various professions. About 60% of the population worked in agriculture, primarily as farmers growing maize, cassava, coconut trees, groundnuts, and cashew nuts on average 2 hectares of garden land per/household. A small percentage (about 5%) of the population kept only a few animals (goats, sheep, cows, and poultry). Most of the time, the animals roamed free in the forests or on fallow land. Just under two percent were involved in fishing for fish, prawns, and crabs in Mwache Creek. In the local area, over 10% of the population worked as teachers either in the site or in neighboring towns (Mombasa, Mazeras, Miritini, Kinango, Kwale, etc.). Kasemeni Division, the focus of this research, is located in Kwale District (Ityeng et al. 2008). The human population in the area grows by 2.6% every year, and the average family there has between 6 and 8 members. Kinango constituency, the poorest in Kenya, is located in this area (Ityeng et al. 2008). Unpredictable weather patterns, inefficient farming methods, and a lack of livestock are to blame for the region's extreme poverty (Ityeng et al. 2008). Those living in extreme poverty have been forced to rely on three forests' illegal and unrestrained logging to make ends meet. Building poles, timber, firewood, and various medicinal herbs were the most commonly harvested by the local community for use in homes and businesses.

**Procedures**

*Reconnaissance survey*

Each forest section was explored on foot for three days to become acquainted with its terrain, vegetation, habitat types, footpaths, and avian inhabitants. Because of differences in disturbance, degradation, and biodiversity, the vegetation in each piece was assigned to one of three categories. The primary habitat comprises the least disturbed typical coastal forest areas in the three sites, still covered by indigenous tree species and shrubs. The secondary habitat consists of highly disturbed sections of the forests cleared of vegetation, bare or regenerating with grass. There are also a few scattered native trees and shrubs planted with exotic species; an aquatic habitat consists of river basins (Mwache and Mbome Rivers). In addition, there is a creek separating MwacheForest Reserve from *Kaya* Mtswakara. Each forest's habitat size was determined visually. Since the primary habitat sections of the three forest fragments represented the remaining indigenous habitat along the coastal forests, those were expected to host the majority of birds typical of this biome, detailed avian (bird ringing). Therefore, the Timed Species Counts (TSCs) and vegetation surveys were limited to these areas. Research assistants were trained in data collecting techniques, and all field methodologies (bird and vegetation survey methods) were evaluated. Three research sites were selected, and the logistics of getting to each one were worked out. Timed Species Counts (TSCs), bird ringing/banding, and opportunistic approaches were used to study the local bird population.

*Timed Species Counts (TSCs)*

TSCs were initially designed to be utilized in savannah environments (Pomeroy and Tengecho 1986). However, a refined version of TSCs was designed, tested (Bennun and Waiyaki 1992), and widely adopted as an efficient and speedy approach to counting birds in the forest's middle and upper canopy (Bennun and Waiyaki 1993). Furthermore, to promote comparability of data across sites, this study focused on conducting detailed bird surveys in the significant habitat part of each forest fragment that included a network of walkways frequented by the local people. To identify and record any birds observed or heard

calling, the observer walked silently along a predetermined course for 40 minutes (Waiyaki 1995; Bennun and Howell 2002). Each interaction also had its associated time, date, distance (within or beyond 25m), kind of contact, number of persons, perching height, and length recorded. The counts were begun at sunrise (06:00) and finished at 10:00 when bird activity reduced substantially throughout the Kenyan beaches (Fanshawe 1993; Waiyaki 1995). Throughout seven mornings, 22 TSCs were carried out in the main parts of the three locations.

*Bird ringing/banding*

Mist netting and bird ringing are helpful methods for surveying the silent and elusive species that inhabit the forest's understory, which is often missed by other forms of detection (Bibby et al. 1998; Bennun and Howell 2002). The bird banding was conducted in the principal parts of the woodland patches. In *Kaya*s, Gandini, and Mtswakara, ringing sites were set up around the sacred forests (the holiest forest area with minimal environmental damage where the local Duruma people held traditional rites). Without a sacred forest to protect in Mwache Forest Reserve, it was decided to preserve the region 500 meters east of the quarries, where the indigenous ecosystem is less likely to have been destroyed than in *Kaya*s. Following the existing pathways, which were cleared of foliage using machetes to a width of one meter, led researchers to the ringing sites, which were spaced between 200 and 500 meters apart. Each ringing location had two net lines, one measuring 60 m (18 m x 2 and 12 m x 2) and the other measuring 54 m (18 m x 3), at intervals ranging from 60 to 100 m. The avian ringing data were collected at three different places in each forest (Laurence et al. 2004). Each woodland fragment was studied for 12 days and 48 hours, with each day consisting of four hours of ringing (05:45-10:15hr). Once each hour, we'd go out and inspect the nets, and before bed or a storm, we'd fold them up. Moreover, to determine species distribution among the patches, all seized birds were retrieved and fitted with an individually numbered aluminum metal ring in one leg and a single colored plastic ring (red for Gandini, yellow for Mtswakara, and blue for Mwache). Additionally, the birds' head, tarsus, wing, bill, weight, and molt scores were measured to get a complete biometric profile.

*Opportunistic bird surveys*

The procedure entailed maintaining a detailed checklist of the area's avian fauna throughout the survey. In this study, researchers explored various habitat types within each forest fragment and those within a 300-meter radius of each location. In addition, each woodland was surveyed for nocturnal (owls and nightjars) birds throughout two nights. Birds were identified by sight and confirming records using the bird identification guide of Kenya and Northern Tanzania by Zimmerman et al. (1999) and using calls based on the bird-watching experiences of the observers.

*Vegetation surveys*

Footpaths paralleling net lines were used to assess the vegetation and look for bird species in the three forest sections. Each forest had ten 10-square-meter plots spaced at least 50 meters from each other and the net. Thirty plots were established around the mist netting in each forest stand to collect data. Additional vegetation data were collected inside 50 plots along footpaths as part of Timed Species Counts (TSCs). First, the height of the canopy was estimated visually, and the result was "the vegetation above 4m," where each "m" stands for one meter. To get a rough estimate of the canopy cover, we used a toilet paper roll to count the number of skylights that were obscured (1l cm long, 4.5 cm diameter). Next, the percentage of low (0-2 m), moderate (3-8 m), and high (>8 m) vegetation was measured using a cylinder 10 m in Diameter. Finally, we counted the number of surviving and dead tree stems within a 5-meter radius from the plot's center, categorizing them by their Diameter into four groups: 5-10 cm Diameter at Breast Height (DBH), 11-20 cm DBH, 21-30 cm DBH, and >31 cm DBH (Fanshawe 1993: Waiyaki 1995). Within a 1 $m^2$ plot, at a distance of 1 m from the plot's center, the percentages of litter, herb, and bare cover were determined.

Canopy tree spacing and sizes were calculated by locating the nearest four trees (>8 m tall) from the plot's center, one in each of the cardinal directions (North, East, West, and South). The distance between each tree and the observer was measured in meters using a mix of pacing and the tree's Diameter at Breast Height (DBH). Finally, we measured the understory thickness and openness of the shrubbery five meters from the plot's center to the North and South, respectively (1 m and 2 m height), using a chequerboard (50 cm × 50 cm with 10 cm x 10 cm red and white squares) (Fanshawe 1993; Waiyaki 1995). The researcher did the measurement and the collection of all the data alone to rule out the possibility of inaccurate results.

*Interviews and observation of human activities*

People living in the areas surrounding the study sites, as well as those who were extracting forest products or grazing animals, were interviewed orally, as were *Kaya* community forest guards in charge of *Kaya* Gandini and *Kaya* Mtswakara. Information about the current state of forest management in the *Kaya*s region, local people's access to forest products, human encroachment into the forests, and community involvement in conservation efforts were gathered using free-form questions (Frost and King 2003). The forest ranger at Mwache Forest Reserve was an excellent resource for learning about quarrying in this area. Field observations collected throughout several visits to each forest, my encounters with community members in the nearby villages, and literature reviews corroborated the information generated through interviews.

**Data analysis**

The diversity of bird species, compositions of feeding guilds, and structural features of the three sections' vegetation were summed up and compared. According to taxonomies provided by Bennun et al. (1996), the recorded bird species were divided into three groups based on their level of forest dependence: forest specialists, generalists, and visitors. All encounters with birds within 25 meters of the observer and three meters in the air were used to

determine the relative abundance of each species (Bennun and Howell 2002). Chi-square analysis was performed to compare the three forest locations for their relative differences in bird feeding guild compositions. Input and organization of vegetation data were done in Ms. Excel 2003 spreadsheets. The percentage data and the log (x+1) converted count data were normalized using arcsine transformation, respectively. Statistical Package for the Social Sciences (SPSS) 12.0 for Windows was utilized to import the data and conduct a thorough analysis. Moreover, to determine whether variables were significantly different between the three locations, a one-way Analysis of Variance (ANOVA) was performed, followed by a post hoc multiple comparisons Turkey test (Lowler and Cohen 1990). The current state of forest management in the *Kaya*s region, including timber harvesting, human encroachment, community involvement in protecting forest sites, and quarrying, was documented through in-depth interviews and on-the-spot observations in the Mwache Forest Reserve.

## RESULTS AND DISCUSSIONS

### Birds

*Bird species richness*

The three locations reported 141 unique bird species. *Kaya* Gandini had the most, with 93 species; *Kaya* Mtswakara and Mwache Forest Reserve came next, with 88 and 91 species, respectively. These species were observed in each forest fragment's primary, secondary, and aquatic/wetland environments. Fifty of Gandini's 93 species were found in the forest's primary habitats. The same was true for Mtswakara (51 species) and Mwache (31 species). Of the total species, 141, 41 were observed in all three fragments, representing 29% of all species. In Gandini, 44% of all species were found in Mwache, while 45% were in Mtswakara. The greatest number of species recorded between the two locations was found in Gandini and Mtswakara (61), followed by Mwache and Mtswakara (58) and Mwache and Gandini (53) (Figure 2).

On the fifth day, the species discovery curves of Gandini and Mtswakara for the primary forest habitats began to level off, indicating that increased searches were unlikely to uncover new species in the two fragments. The curve of Mwache, on the other hand, leveled off slightly on the seventh day (Figure 3), indicating that subsequent avian surveys may identify new bird species.

From a total of 141 bird species observed across all sites, only nine (6%) were classified as forest specialists, compared to 29 (21%) generalists, 27 (19%) visitors, and 76 (54%) nonforest species. There were more specialized species in Gandini than elsewhere (Table 1). With 34 species, Gandini has more forest species (generalists and specialists) than Mwache and Mtswakara, with 25 species reported. There were substantial differences between specialists ($x^2$ test P=17.37, 2 d.f), generalists ($x^2$ test P=55.94, 2 d.f), visitors ($x^2$ test P=51.36, 2 d.f), and nonforest birds ($x^2$ test P=146.6, 2 d.f) in various forest sections.

**Table 1.** A brief synopsis of the significant groups of forest bird species found in isolated forest areas in Kenya: Gandini had a higher concentration of forest birds than the other fragments, but Mwache had a greater variety of nonforest species

| Bird categories | Gandini | Mtswakara | Mwache | Totals** |
|---|---|---|---|---|
| Forest specialists | 8 | 4 | 5 | 9 |
| Forest generalists | 26 | 21 | 20 | 29 |
| Forest visitors | 21 | 20 | 18 | 27 |
| Nonforest birds | 38 | 43 | 48 | 76 |
| Totals* | 93 | 88 | 91 | 141 |

Note: * the total number of species recorded at each site is the same as the total number of species recorded under each category; ** the total number of species recorded at all three fragments is not equal to the numbers recorded under each category because of common species recorded in more than one site

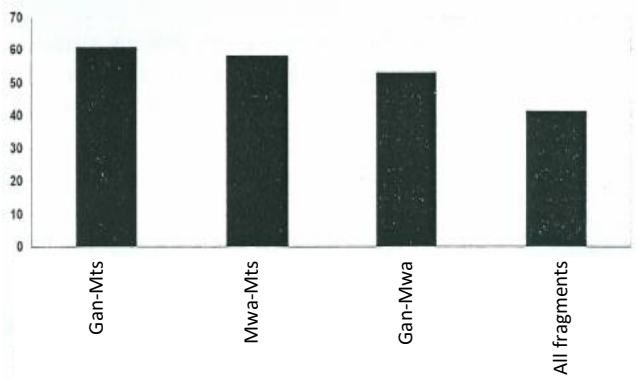


**Figure 2.** The number of common bird species seen in two separate fragments. Overlapping species (those found in more than one location) are listed below. The greatest variety of widespread bird species was found in Gandini and Mtswakara (Kenya). Gan: Gandini, Mts: Mtswakara, Mwa: Mwache

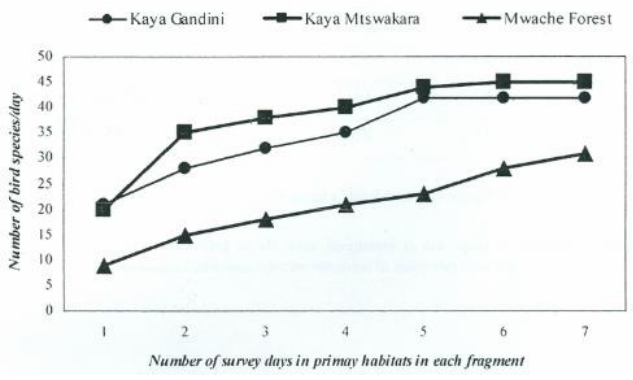


**Figure 3.** The Depicts of the species discovery curves of the three forest fragments' significant habitats. Additional surveys may uncover new bird species in Mwache's primary habitats, but it is doubtful that this will occur in Gandini and Mtswakara (Kenya)

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

The three locations housed four internationally endangered bird species: the Fischer's turaco, the Southern banded snake eagle, the plain-backed sunbird, and the Sokoke pipit. The number of species varied from island to island; Gandini had four, Mtswakara had two (Fischer's Turaco and Plain-backed Sunbird), and Mwache had three (Fischer's Turaco, Plain-backed Sunbird, and Sokoke Pipit) (Table 2). No sightings of the Spotted Ground Thrush, which had been documented in the area before, were made. No sightings of the thrush were made at Mwache or Mtswakara. More Fischer's Turacos were found in Gandini, where their sounds could be heard virtually daily in the primary habitat first thing in the morning. Throughout the research period, just two turacos were spotted or heard in the Mwache and Mtswakara areas. While Mwache and Mtswakara are the most common primary habitats for Plain-backed Sunbirds, they have also been spotted in Gandini's sacred forest. The Southern Banded Snake Eagle and the Plain-backed Sunbird were discovered in Gandini and Mtswakara. In Gandini, the Southern Banded Snake Eagle and Sokoke Pipit were so uncommon that they were only seen once. No sightings of Southern Banded Snake Eagle, which had been spotted in Mtswakara in the past made at this location.

A total of 14 bird species native to the East African Coastal Biome Bird Species (EACBs) were registered over the three locations, accounting for around 10% of all bird species in Africa. Kenya was home to nearly half (14/30 species) of all bird species found in the East African Coastal Biome Bird Species (EACBs). There were the same amount of EACBs in Gandini and Mwache but fewer species in Mtswakara (Table 3).

Black-bellied Starlings (*Lamprotornis corruscus mandamus*), Brown-headed Parrot (*Poicephalus cryptoxanthus*), and Mombasa Woodpeckers (*Campethera mombassica*) were more prevalent in fragments where they were documented. In forests where they were exceptionally documented, the 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*. Southern Banded Snake Eagle, Sokoke Pipit, Plain-backed Sunbird, Scaly Babbler (*Turdoides aylmerikenianus*), and Chestnut-fronted Pipit. Helmet-shrike (*Prionopsscopifrons kirki*) were extremely rare and were only observed or heard calling once in the location where they were documented.

*Bird dispersal within fragmented forests*

Researchers captured and ringed 59 individuals representing 12 different species using aluminum and plastic of different colors in the three woodland fragments. Most species and individuals were found in Gandini (10 total), while only four were found in Mtswakara, and only three were found in Mwache. The highest number of individuals was the Red-capped robin chat (*Cossypha natalensis*) (26), followed by the Eastern-bearded scrub robin (*Cercotrichas quadrivirgata*) (5) (Table 4). Gandini nevertheless had higher species richness and abundances on the Red-capped Robin-chat, an Afro-tropical migrant bird that visits Kenya yearly between April and November (but was unavailable at several sites when ringing was being conducted), which was removed from the analysis. There were no captures or sightings of individuals of a species outside of the original ringing segment. On the other hand, to put it another way, no ringed individual was seen to scatter from one piece to the other.

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

| Globally threatened bird species | Gan | Mts | Mwa |
|---|---|---|---|
| Fischer's Turaco | R* | R* | R |
| Southern banded snake eagle | R** | NR | NR |
| Plain-backed Sunbird | R* | R** | R |
| Sokoke Pipit | R* | NR | R |
| Spotted Ground Thrush | NR | NR | NR |
| Total (species recorded) | 4 | 2 | 3 |

Note: Species previously recorded (*), spp not recorded in the past (**), surveys done at the site for the first time (+), R-recorded, NR-not recorded. Gan: Gandini, Mts: Mtswakara, Mwa: Mwache

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

| Bird species | Gan | Mts | Mwa |
|---|---|---|---|
| Black-bellied Starling | R | R | R |
| Brown-breasted Barbet | R | R | R |
| Brown-headed Parrot | R | R | - |
| Fischer's Greenbul | R | R | R |
| Fischer's Turaco | R | R | - |
| Mombasa Woodpecker | R | R | R |
| Mouse-colored Sunbird | - | - | R |
| Northern Brownbul | - | R | R |
| Plain-backed Sunbird | R | R | R |
| Southern Banded Snake Eagle | R | - | - |
| Scaly Babbler | - | - | R |
| Chestnut-fronted Helmet Shrike | R | - | - |
| Zanzibar Red Bishop | - | - | R |
| Sokoke Pipit | R | - | R |
| Total (species recorded) | 10 | 8 | 10 |

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

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

| Bird species | Gan | Mts | Mwa | Total |
|---|---|---|---|---|
| Red-capped Robin-Chat | 26 | 2 | - | 28 |
| Eastern Nicator | 5 | 2 | 2 | 9 |
| Eastern-bearded Scrub Robin | 5 | 1 | 2 | 8 |
| Narina Trogon | 3 | - | - | 3 |
| Olive Sunbird | 1 | - | - | 1 |
| Red-tailed Ant Thrush | 1 | - | - | 1 |
| African Goshawk | 1 | - | - | 1 |
| Yellow-bellied Greenbul | 1 | - | - | 1 |
| Blue-mantled Crested Flycatcher | 1 | - | - | 1 |
| Tambourine Dove | 1 | - | 1 | 2 |
| Ashy Flycatcher | 1 | - | - | 2 |
| Collared Sunbird | - | 2 | - | 2 |
| Totals (individuals) | 47 | 7 | 5 | 59 |

Note: (-) not recorded/captured4.2.4 Relative Abundances of Bird Species

For the examination of TSCs data in a forest situation, Pomeroy and Tengecho (1986) and Bennun and Howell (2002) found that only 49 species across all locations satisfied their criteria. Twenty-nine of these species were found in Gandini, 33 in Mtswakara, and 27 in Mwache. Seven forest species with the highest abundance scores were found in Gandini, three were in Mtswakara, and two were in Mwache; all told, 12 species were present throughout all three sites. The Eastern-bearded Scrub Robin has supplanted the Grey-backed Camaroptera (*Camaroptera brevicaudata*) as the most numerous species in Mtswakara and Mwache. Eastern Nicator (*Nicator gularis*), Olive Sunbird (*Nectarinia olivacea*), and Collared Sunbird (*Anthreptes collaris garguensis*) were also common across all three sections. The Little Sparrowhawk (*Accipiter minullus*), the Brown-headed Parrot, and the Great Sparrowhawk (*Accipiter melanoleucus*) were the three species with the lowest abundance scores in Gandini. Birds such as the Green Wood Hoopoe (*Phoeniculus purpureus*), the Martial Eagle (*Polemaetus bellicosus*), and the Plain-backed Sunbird were unusual in Mtswakara, while the Northern Brownbul and the African Paradise Flycatcher (*Terpsiphone viridis*) were scarce in Mwache.

The abundance distributions of six forest-dwelling specialized taxa (FF) were examined. The Olive Sunbird was the only one to appear in all of the different parts, and it was found in the highest numbers in Mtswakara. Only in Gandini and Mtswakara were the Red-tailed ant thrush (*Neocossyphus rufus*) and the African crowned eagle (*Stephanoaetus coronatus*) documented, albeit at extremely low relative abundances (Table 5).

The abundance distributions of seventeen forest generalist species (F) were compared across the three sites. Six of these species were found in all fragments, whereas the rest were only found in either one or two locations (Table 6). While the Collared Sunbird was more common in Mtswakara, Gandini was home to the Eastern Nicator, African Goshawk (*Accipiter tachiro*), Yellow-bellied Greenbul (*Chlorocichla flaviventris*), Mombasa Woodpecker, and Great Sparrowhawk. Mwache was home to a larger population of the Tambourine Dove (*Turtur tympanistria*), Black-backed Puffback (*Dryoscopus cubla*), and the Crested Guineafowl (*Guttera pucherani*) (Table 6).

The abundance distributions of six species native to the coastal biome were analyzed. All three locations had Mombasa Woodpeckers, but the population density was highest in Gandini, Mwache, and Mtswakara (Table 7).

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

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

Note: (-) not recorded

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

| Bird species | Gandini | Mtswakara | Mwache |
|---|---|---|---|
| Eastern Nicator | 3.09 | 3.05 | 2.73 |
| African Goshawk | 2.95 | 2.18 | 2.18 |
| Trumpeter Hornbill | 2.55 | - | - |
| Yellow-bellied Greenbul | 2.73 | 2.32 | 2.23 |
| Collared Sunbird | 2.55 | 2.95 | 2.64 |
| Mombasa Woodpecker | 2.36 | 2.18 | 2.27 |
| Ashy Flycatcher | 2.23 | 2.18 | - |
| Fischer's Turaco | 2.23 | - | - |
| African Wood Owl | 2.09 | 2.09 | - |
| Greater Sparrowhawk | 2.09 | 2.05 | 2.14 |
| Brown-headed Parrot | 2.05 | - | - |
| Mottled Spinetail | - | 2.18 | - |
| Fiery-necked Nightjah | - | 2.09 | 2.36 |
| Tambourine Dove | - | - | 2.14 |
| Black-backed Puffback | - | - | 2.18 |
| Crested Guineafowl | - | - | 2.18 |
| Total (species recorded) | 11 | 10 | 10 |

Note: (-) not record

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

| Bird species | Gandini | Mtswakara | Mwache |
|---|---|---|---|
| Fischer's Greenbul | 2.45 | 2.36 | - |
| Mombasa Woodpecker | 2.36 | 2.18 | 2.27 |
| Fischer's Turaco | 2.23 | - | - |
| Brown-headed Parrot | 2.05 | - | - |
| Plain-backed Sunbird | - | 2.05 | 2.18 |
| Northern Brownbul | - | - | 2.05 |
| Totals (species recorded) | 4 | 3 | 3 |

*Bird-feeding guilds compositions*

For this analysis of bird feeding guilds, we utilized data from TSC counts, which revealed 65 species of forest birds (specialists and generalists) and visitors. The insectivores comprised 49% of the species found across the three locations. Followed by the carnivores (15%), granivores (15%), omnivores (9%), and the frugivores and nectarivores (both 8%), respectively. It was found that the insectivore diversity in Gandini was higher than that in Mwache and Mtswakara, which both had 31% (Mie P=76.62, 5 d.f). (Table 8). Carnivore Oxia populations varied significantly between forest types (P=25.38, 5 d.f.). However, the number of documented frugivores, granivores, nectarivores, and omnivores was consistent throughout forest types.

## Vegetation structure

*Forest litter cover, understory (0-3 m), and canopy (>4 m) cover*

Many dead leaves and branches littered the woodland floor at all three locations (open areas). However, the litter, plant, and bare ground cover in the three forest patches did not differ significantly (Table 9). Lower vegetation thickness was similar throughout the three forests, as was the degree of openness at 1 m and 2 m. Gandini and Mtswakara have the same canopy cover (CC-above 4 m) and high canopy cover (HCC-above 9 m) as compared to Mwache (Table 10). Gandini and Mwache had the same

Medium Canopy Cover (MCC-(3-8 m), but Mwache had a distinct MCC (3-8 m) (Table 10).

*Comparison of vegetation structure among forest fragments*

Seventy-one percent (20/28 variables) of the plant structure between the three pieces was the same, with only twenty-nine percent (8/28) being different. Coverage of the canopy, height of the canopy, high canopy cover, average tree diameter, and the number of living stems are all terms used in this context. The Gandini and Mtswakara had the same, and Mwache had a different diameter at breast height (DBH) of 21-30 cm and >31 cm, respectively. Gandini and Mwache both have medium canopy cover and cut stumps DBH 11-20 cm. Overall, Gandini and Mtswakara were more comparable to one another in terms of vegetation structure than Mwache, with 26 ((93%, (26/28) factors being the same (Table 10).

*Relationship among vegetation variables*

The forest's canopy cover was affected by tree diameter, canopy height, and the presence or absence of large, standing trees (>31 m in circumference). This correlation was statistically significant (F4, 235=113.620, p<0.0009, r'=0.659). Canopy cover differences between forest patches were explained by 65.9% of these factors. Medium canopy cover, canopy cover, understory vegetation cover at l m and 2 m, and lower canopy cover were all predictive of litter cover on the forest floor. The significance level of this correlation was extremely high (Fs, 234=38.18, p<0.0001, r'=0.449). Those factors accounted for 44.9% of the total variance in litter cover.

**Table 8.** Bird feeding guilds compositions of the three forest fragments

| Feeding guilds | Gandini | Mtswakara | Mwache | Total |
|---|---|---|---|---|
| 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 |

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

**Table 10.** Mean comparisons of vegetation factors across forest patches (n=80 per plot, Turkey test for all variables showing statistical significance using one-way ANOVA) (S=Same, D=different)

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

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

| Variable | N=80 plots/site | Gandini | Mtswakara | Mwache | p-values |
|---|---|---|---|---|---|
| Canopy Cover | Mean | 40.09±3.51 | 39.2S±3.17 | 19.58±3.07 | 0.0007* |
| Canopy Height | Mean | 17.10±3.17 | 12.39±0.92 | 3.81 ±0.46 | 0.0008* |
| Lower Canopy Cover (0-2m) | Mean | 40.38± I. 71 | 41.69±2.36 | 3S.94±1.62 | 0.089 |
| Medium Canopy Cover (3-8m) | Mean | 15.13±1.08 | 9.81±101 | 19.38±1.68 | 0.0002* |
| High Canopy Cover (>8m) | Mean | 9.38± 1.14 | 6.S8±0.71 | 1.38±0.37 | 0.0085* |
| Tree Distance (m) | Mean | 7.35±0.300 | 7.03±0.46 | 7.29±0.49 | 0.S59 |
| Diameter at Breast Height (DBH (rn) | Mean | 34.72±1.46 | 28.99±1.19 | 18.93±1.14 | 0.0002* |
| Live Stems (5-1 Ocm) | Count | 130 | 84 | 134 | 0.380 |
| Live Stems ( 11-20cm) | Count | 62 | 69 | 59 | 0.712 |
| Live Stems (21-30cm) | Count | 65 | 73 | 29 | 0.0002* |
| Live Stems (>3Icm) | Count | 47 | 61 | 16 | 0.0002* |
| Dead Standing Stems (5-1 Ocrn) | Count | I | 0 | 0 | 0.369 |
| Dead Standing Stems (11-20cm) | Count | 0 | I | 2 | 0.366 |
| Dead Standing Stems (21-30cm) | Count | I | 0 | 0 | 0.369 |
| Dead Standing Stems (>31 em) | Count | 2 | I | 0 | 0.366 |
| Dead Floor Stems (5-1 Ocm) | Count | 9 | I | 7 | 0.255 |
| Dead floor Stems ( 11-20cm) | Count | 4 | I | 3 | 0.408 |
| Dead Floor Stems (21-30cm) | Count | 2 | 0 | 0 | 0.369 |
| Dead Floor Stems (>3Icm) | Count | I | I | 0 | 0.607 |
| Cut Stumps (5-1 Ocm) | Count | 335 | 331 | 255 | 0.207 |
| Cut Stumps ( 11-20cm) | Count | 32 | 61 | 19 | 0.0001* |
| Cut Stumps (21-30cm) | Count | 21 | IS | 6 | 0.44 |
| Cut Stumps (>3Icm) | Count | 12 | 10 | 3 | 0160 |
| Vegetation Density at l m | Mean | 57.05±2.64 | 50.25±3.22 | 57.28±2.19 | 0.118 |
| Vegetation Density at 2m | Mean | 54.95±2.74 | 56.93±3.08 | 54.6S±2.39 | 0.817 |
| Litter Cover | Mean | 74.63±2.55 | 62.56±3.16 | 75.80±2.22 | 0.103 |
| Bare Cover | Mean | 19.13±2.44 | 26.49±2.90 | 16.11±1.70 | 0786 |
| Herti Cover | Mean | 6.25±0.83 | 10.56± 1.70 | 8.15±1.55 | 0.101 |

Note: Gan: Gandini, Mts: Mtswakara, Mwa: Mwache, SIL: significant level, * factors that vary noticeably between locations

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

| Tree/stump size | Trees/stumps | Gandini | Mtswakara | Mwache | Overall |
|---|---|---|---|---|---|
| Small trees (5-10 cm DBH) | Live tree | 38.8 | 25.4 | 5.25 | 27.4 |
| | Cut stump (dead/alive) | 61.2 | 74.6 | 47.5 | 72.6 |
| Small-medium (11-20 cm DBH) | Live tree | 66.0 | 53.1 | 75.6 | 62.9 |
| | Cut stump (dead/alive) | 34.0 | 46.9 | 25.1 | 37.1 |
| Medium-large (21-30 cm DBH) | Live tree | 75.6 | 83.0 | 82.9 | 79.9 |
| | Cut stump (dead/alive) | 24.4 | 17.0 | 17.1 | 20.1 |
| Large tree (>31 cm DBH) | Live tree | 79.7 | 85.9 | 84.2 | 83.2 |
| | Cut stump (dead/alive) | 20.3 | 14.1 | 15.8 | 16.8 |

Note: Gan: Gandini, Mts: Mtswakara, Mwa: Mwache

*Levels of regeneration and logging*

Each forest had a unique mix of stumps, which indicates the removal of live trees, and standing trees, which indicates that the forest had regenerated. Each forest had 80 plots surveyed to determine the logging and regeneration rates by tallying the number of live trees and cut stumps in each Diameter at the Breast Height (DBH) category. The rate of logging or regeneration was estimated by dividing the number of living trees or cut stumps in each category by the total number of living trees and cut stumps in each fragment. In all forests, the rate at which young trees (DBH 5-10 cm) were cut down was higher than the rate at which trees of larger sizes (DBH >11 cm) were felled. Mtswakara, followed by Gandini and then Mwache, had the highest rate of young tree logging. Generally speaking, loggers avoided cutting down trees that were over 21 centimeters in Diameter at the breast. The pace at which trees of all types were cut down was significantly lower in Mwache than in Mtswakara and Gandini (Table 11). Trees in Mwache and Gandini were the same height and Diameter, while Mtswakara trees were much smaller. The total number of dead standing and floor stems in all the forests studied was low. Large, living trees (DBH>31 cm) were scarce across all three forests.

**The conservation status of the forest fragments**

*The management structure of kayas forests*

Under the Monument and Antiquities Act Cap 215 of 1983, the NationalMuseums of Kenya (NMK) is responsible for safeguarding the *Kaya* forests (Gandini and Mtswakara), which it does through the Coastal Forest and Conservation Unit (CFCU) of its sites and monument office. The *Kaya*s forests in Kenya were included on the UNESCO World Heritage List in July 2008. Since the Mijikenda communities (Kauma, Chonyi, Jibana, Giriama, Kamabe, Ribe, Rabai, Duruma, and Digo) have traditionally used the *Kaya*s for ceremonial purposes, the NMK administration has been preserving the forest with their help. A group of respected elders has traditionally and currently controlled the process by which forest resources are taken from the forest land of the *Kaya*s. In 2007, *Kaya* Gandini Important Bird Area was managed by a 12-person committee comprising the council of elders and eight community forest guards. The Duruma community worked with the Central Financial Credit Union of Uganda (CFCU-Ukunda) and provincial officials to form the committee (chief and assistants). Four guards made their homes and ran their businesses on the eastern side to ensure the entire forest was being watched while the other guards patrolled the western side. According to interviews with locals, the *Kaya* Mtswakara council of elders has not had an operating committee since 2003, but it was revived at the beginning of 2007. The local people's extraction of forest products continued unchecked during the council's absence. Four local forest guards were hired in 2007 when the unit was formed to aid in patrolling the *Kaya*.

Gandini and Mtswakara each had a council of elders with a chairman, vice chairman, and secretary. When town residents needed certain Kayas forest products, they went to the council's chairman. For example, it was agreed that residents of certain *Kaya*s could cut down trees with a diameter between 5 and 10 centimeters to use as building materials and firewood. In 2007, villagers paid 600 (Ksh.) to the council of elders for permission to extract the poles needed to construct a tiny, two-bed chamber traditional hut from *Kaya* Gandini. The costs associated with holding communal ceremonies, such as the purchase of goat, sheep, cow, castor oils, etc., were covered by the levies and fines imposed on offenders captured in the forest. Furthermore, in 2007, a large portion of the funds was allocated to prosecuting those caught illegally poaching trees from the forest without permission from the chairman of the council. If necessary, the perpetrators were denounced to the chiefs and then sent to Kwale to face prosecution.

The eight guards hired in 2006 to keep watch over Gandini had dwindled to four by the end of 2007, with the other four quitting altogether. Out of the original four community guards hired for Mtswakara, only two were doing any patrolling. These forest rangers served their communities on a strict volunteer basis without compensation. As a result, they were free to abandon their patrol responsibilities whenever they had to tend to more press matters. The community guards had begun stealing trees from both *Kaya*s instead of protecting them as planned. No money was given to either *Kaya*'s chairman in 2007 or 2008 by locals hoping to remove poles from their respective *Kaya*s. There was an increase in pole cutting, and it appeared that the local populace no longer respected the council of elders. Most of the guards and council members' morale had plummeted, and they were gloomy about continuing their task. The council of elders had previously outlawed using machetes and axes for harvesting tree branches and firewood, yet this practice persisted unchecked in both *Kaya*s.

The guards of the two sacred forests and the council of elders had lost faith in the local administration (chiefs and their helpers), with whom they were expected to coordinate to collect fines levied by the council of elders. Due to conflicts of interest, there were frequent disagreements between the Kayas council of elders and the local administration. The chief of Mtswakara abolished the council of elders and reorganized it without informing the CFCU headquarters in Ukunda. In addition, some tree poachers captured in Gandini and turned over to the local authorities were released without paying the mandated fines or facing any further action. The guards and elders were put in an extremely tough, nearly hopeless situation due to the inability of three stakeholders (council of elders, local government administration, and NMK-CFCU officials) to effectively work in prosecuting those responsible for damaging the *Kaya*s.

The introduction of new technologies and the expansion of civilization had eroded Duruma's customs and beliefs. Among the Duruma people, especially the younger generation, there was a disrespect for the holiness of the *Kaya*s. Visitors have reported trees being hacked down in the Gandini and Mtswakara sacred forests. The forest was considered the holiest spot in a *Kaya*. All community members could quickly and readily locate the sacred forest thanks to a circular trail roughly 2 meters wide and completely devoid of vegetation. Ancient rituals were performed here under the watchful eye of the elders. A vast buffer zone encircled the forest of at least Iha, allowing locals to legally harvest forest products once they had approval from the village council. Despite these management difficulties, the Gandini council was marginally better organized, devoted, and coordinated in its conservation of the sacred forest than the Mtswakara council was. The council of elders and the guards under their charge all exuded an impressive dedication to protecting *Kaya*s and Duruma culture.

*Extraction of forest products by local people*

The three wooded locations were "islands" surrounded by people on all sides. Most of the Durumas populace works in agriculture, mainly cultivating coconuts and other tropical fruits and vegetables like maize, cassava, and groundnuts. In addition, they had some livestock, such as cows and goats. Animal husbandry, however, was embracing zero-grazing or was being phased out entirely due to the limited amount of land per household (1 *sha* or less). As a result, agriculture and human settlements were transforming the entire region around *Kaya*s Gandini and Mtswakara into environments unfavorable for the preservation of forest bird species. More than 90% of the inhabitants living within 3 km of the forests relied on the *Kaya*s as their primary source of building poles. Young trees (20 cm in Diameter at breast height (DBH)) were removed selectively for construction, while larger trees (20 cm DBH) were removed for timber. With hand saws, locals in Gandini andMtswakara harvested specific trees for their lumber. Poles used in construction ranged in Diameter from 5 to 10 cm; they were topped with dried, old coconut leaves (*makuti*). Even if some were sold in the nearby village towns 10-20 km away, the *Kaya*s were the primary source of firewood utilized by the local people who lived within 3 km of the forest for cooking. The elders permitted the ladies to collect only the dead trees, and they were forbidden to use tools other than their hands. However, this prohibition was often disregarded since women brought these implements into the *Kaya*s to be used by men to remove dead trees that could not be broken with bare hands. Each *Kaya* was visited daily by more than thirty individuals (women and children) in search of firewood. The main reason leading to the increasing deterioration of the forest ecosystem at Gandini and Mtswakara was the extraction of poles and firewood for sale in the neighboring retail centers and towns.

The Mwache Forest Reserve is just 15 km from Mombasa Metropolis, Kenya's second-largest city, and is located just 1 km off the Mombasa-Nairobi Highway (Figure 1). Approximately sixty percent of the forest's surrounding region was inhabited by locals and utilized for farming. More than 70% of homes and most other household structures in rural areas and neighboring towns relied on building poles sourced from Mwache, the nearby mangrove areas, and some from the *Kaya*s. There was a housing development boom due to the rapid growth in Mazeras and Miritini, as people needed places to live close to their places of employment in the city. As a result, young trees in the Mwache Forest and the mangroves' environment were illegally poached to meet the surging demand for new homes. In addition, a small number of large trees were cut down to provide lumber for local furniture production or for sale to generate some revenue for families.

From the 1970s until the 1990s, the Forest Department (now known as the Kenya Forest Service, or KFS) issued logging permits to residents of Kenya. Large hardwoods were the primary trees cut down back then. Although logging was banned in Mwache from 2007-8, illicit tree poaching was hard to stop. This is because a single unarmed forest guard monitored the entire forest area with the help of two other staff members (one involved in tree nursery management and the other in supervising quarrying activities). In addition, there was a significant issue at Mwache with gathering firewood for domestic consumption and export to other settlements. More than fifty women would visit the forest daily, armed with machetes and occasionally axes, in search of firewood. This machinery could easily break down and remove any dead trees. Observers have seen living trees being cut and taken away as firewood. Much of the forest's firewood and building poles were supplied to consumers in the nearby cities of Miritini, Mazeras, and Mombasa, where the need for these materials was particularly great.

*Human encroachment into the forests*

Some residents had begun intruding into the forests, clearing out some of these fragments for cultivation and settlements. Before the early 1990s, the *Kaya*s were officially protected through a gazette notice. When the National Museum of Kenya declared *Kaya* Gandini and Mtswakara national monuments in 1992, residents were

forcibly removed from the area. In 2007-2008, indigenous trees were slowly growing in the barren and open regions previously inhabited by people, together with cashew nut, coconut, and mango trees left behind by evicted residents. Two families called Gandini home in January 2008. They built their homes in the forest and farmed there, clearing a patch of trees yearly to make way for their crops. A third family began clearing an area for farming and, most likely, constructing dwellings in the forest in August of 2008. A total of about four hectares was being farmed and settled upon by the three households. They were undoubtedly engaged in constant timber exploitation without consulting the elders' council. Neither Mtswakara nor Mwache was ever inhabited.

*Quarrying*

In Mwache, quarrying was one of the most pressing conservation concerns. About 40% of the forest was made up of rocks, many of which were at least twenty meters below ground. Road gravel might be made from these rocks because of their durability. As of March 2008, Mwache was home to four quarries owned by separate businesses. These businesses were all situated along a murram road that wound its way through the forest in roughly the same general area. Even though there were only three quarries before data collection began in October 2007, during that month and the following one, in January 2008, a fourth was opened. In the researcher's estimation, the longest distance between the farthest and nearest quarry along murram road was around 600 m. It was believed that the breadth of the land occupied by the quarries on either side of the road was 400 meters, for a total of 28 hectares (700 m x 400 m = 28,000 $m^2$ /10,000 $m^2$ (1 ha =10,000 $m^2$). About 80% of the native trees and plants had been cut down, severely damaging the environment. The colonialists who introduced quarrying to Mwache did it in the 1950s. It went on for a long time, for some reason, and then halted and started again without intermission in 1992.

The loss of Mwache's pristine habitats to quarrying wasn't the only conservation issue leading to a drop in species numbers. There were a total of 80 persons working in the two quarries. Large rock-hauling trucks, road graders, caterpillars, and ballast graders were available from each business. As a result, there was a lot of commotion from the machinery used for the rock excavation. Large and deep-seated rocks were blasted using explosive chemicals, which resulted in the loudest noise. The blast was thunderous and could be felt more than five kilometers from the explosion's epicenter. Since the stone quarries were quite close to the middle of the forest, it was a serious issue.

*Community participation in the conservation of forest sites*

The locals living in close proximity to the three forest areas rely on the pieces as a source of firewood and building poles for their homes and businesses. While some villagers may have taken the initiative on their own or as part of a larger group, the vast majority of the Kayas and Mwache Forest Reserve residents were not doing anything to improve the situation. There was constant friction between community guards working in Gandini and Mtswakara and locals illegally logging trees. No Community-Based Organizations (CBOs) help the council of elders, Kenya Forest Service, or National Museums of Kenya protect these forests. However, a Community-Based Organization (CBO) called Mwache Forest Community Conservation Organisation was established in Mwache Forest Reserve on 24 July 2008. In August 2008, the organization had already taken significant steps toward registering the CBO with the Ministry of Social Services. The main objective of the CBO was to preserve Mwache by re-afforesting (tree planting) the forest and aiding in patrolling the forest reserve, including the mangrove forest areas. The 345 acres of Mwache woodland had previously been monitored unsuccessfully by a single KFS forest guard. In August of 2008, CBO members were known to patrol the forest twice daily, once in the morning and once in the evening, in mixed groups of at least five persons. They helped the Mwache forest patrol catch people stealing timber (Figure 4). The illegal cutting down of trees within the reserve has been much decreased due to this strategy. The group, however, lacked capacity in the following areas: operating and management of CBOs; fundraising; tour guiding; beekeeping; agro-forestry; eco-tourism development activities; bird watching; and launching and running rural-based companies.

**Figure 4.** In August 2008, members of the Mwache Forest Community Conservation Organisation apprehended a person illegally removing building poles from Mwache Forest Reserve, Kenya (mangrove part)

**Discussions**

The combined areas of Mwache Forest Reserve (345 ha), *Kaya* Gandini (150 ha), and *Kaya* Mtswakara (247 ha) were 742 ha. One hundred forty-one different types of birds have been spotted here. Two hundred thirty bird species have been spotted in Kenya's Arabuko-Sokoke Forest, the country's largest (41,600 ha) continuous coastal forest (Fanshawe 1993; Bennun and Njoroge 1999). To put that in perspective, the Arabuko-Sokoke Forest is roughly 56 times larger than the three forest fragments. Consequently, despite Gandini, Mtswakara, and Mwache being relatively few fragments, the species richness in the three sites was excellent despite their modest size. On top of that, 14 different East African Coastal Biome Bird Species (EACBs) were spotted, accounting for 47% of the total number of EACBs found in the coastal forest biome habitat of Kenya (Bennun and Njoroge 1999). Small coastal forests included in the Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya Biodiversity Hotspot are critically important to biodiversity because of the high species richness and concentration of EACBs in a compact region (Burgess et al. 2003).

Birds that only live in forests were more numerous in Gandini. The bigger the diversity of specialist bird species in a forest, the better the quality of the forest's environment (Bennun and Howell 2002). It is because these specialist birds can only survive in relatively undisturbed habitats. For example, the African Crowned Eagle is a known forest specialist only spotted in Mwache. Despite this, the three forest patches were so close together that they could as well have been one large area of forest separated only by river valleys, as they shared nearly the same types of plant and degrees of forest damage. Therefore, the eagle, a raptor that needs broad territories for its survival (Bennun and Howell 2002), is probably using the three locations for feeding and nesting. In Gandini, the sacred forest is the only known habitat for several specialist bird species, including the Black-headed Apalis (*Apalis melanocephala*). Outside of the forest, no specimens of this species were located. Some species of trees may never leave a tiny patch of woodland where they were born, as pointed out by Newmark (1991). These creatures are likely timid and highly sensitive to changes in their environment.

Seven specialist bird species were documented by Waiyaki (1995) at Gandini, while three were found in Mtswakara. Thirty-one forest species (generalists and specialists) were reported in Gandini and twenty-three in Mtswakara (Waiyaki 1995). Eight specialists and thirty-four forest species were documented in Gandini, while four specialists and twenty-five forest species were recorded in Mtswakara. Therefore, the population sizes of these species in these two pieces changed very little over the last 13 years (1995-2008). Moreover, bird populations are a good indicator of ecosystem health (Furness and Greenwood 1993). The fact that species richness has remained relatively stable in both Mtswakara and Gandini over time indicates that neither site's habitat condition has undergone significant structural change. However, the health of these forests' habitats might be gauged by comparing the concentrations of several specialist bird species throughout the same survey period.

There were the same amount of forest species in both Mtswakara and Mwache. However, Mwache (173 ha) and Mtswakara (124 ha), with far more land, should have been more abundant with specialist birds or even coastal biome species than the 90 ha of pristine coastal regions that existed in Gandini. Likely, the principal habitat of birds fared better in Gandini, a small, undisturbed area, than it would have in Mtswakara or Mwache. In large, Gandini proved crucial in protecting avian diversity compared to other forests.

Four globally vulnerable bird species were found in every surveyed forest: the Plain-backed Sunbird, the Southern Banded Snake Eagle, the Fisher's Turaco, and the Sokoke Pipit. A total of four species were found in Gandini, with just the Spotted Ground Thrush (previously recorded in the region) missing (Waiyaki 1995; Bennun and Njoroge 1999). Since the thrush is a migratory species that only appears in Kenya from April to October each year, it is highly improbable that this study would have captured it. The research period began in late October 2008 and ended in March 2009. (Zimmerman et al. 1996). Large amounts of litter were found in most of the forests, making these three fragments excellent habitats for the Spotted Ground Thrush (Bennun and Waiyaki 1991).

In earlier research, Fischer's Turaco and Southern-banded Snake Eagle were identified in Mtswakara (Waiyaki 1995). The Southern Banded Snake Eagle was not spotted in this survey, but the Fischer's Turaco and the Plain-backed Sunbird were. The Southern Banded Snake Eagle and the Plain-backed Sunbird, both critically endangered, were first spotted in Gandini and Mtswakara, respectively. Mwache was surveyed for the first time for birds, and three species that are critically endangered or extinct everywhere in the world were found there. Except for Fischer's turaco, all other threatened species were scarce, with only a handful of individuals ever being heard calling or seen. Fischer's turaco was spotted or heard calling at all study sites, but its numbers were highest in Gandini. For instance, the variety of frugivorous bird species and their foraging behavior are influenced by the availability of fruiting plants (Moegenburg and Levey, 2003). (Levey 1988). Thus, there are likely more fruiting trees in Gandini than in other places the turacos could go to eat (fruits).

Insectivores (animals that eat insects and other invertebrates via sallying, back gleaning, and other methods) were the most numerous eating guild in all forests. According to Blake and Loiselle (2001), insectivores are the most numerous and diverse guilds in tropical forests, with a wide range of feeding styles. The insect life in Gandini was greater than in the other two forests. Some bird feeding guilds may be good indicators of how badly a forest is being deteriorated. For instance, once a forest was disturbed, the number of insects that lived there decreased (Gray et al. (2007). Insectivore search behavior may be significantly affected by the environment's structural complexity and light regime, both of which change considerably in response to disturbance

(Barlow et al. 2002). (Rosenberg 1993). Therefore, the drop in insectivore abundance in Mwache and Mtswakara forests may have been caused by habitat disturbance and fragmentation. In each forest, only a small number of species of carnivores, frugivores, granivores, nectarivores, and omnivores were present. Those findings make it difficult to identify any consistent dietary structure among them. The reactions of carnivores, nectarivores, and omnivores were less evident in an analysis of feeding guilds' composition following habitat disturbance conducted by Gray et al. (2007). However, Gray et al. (2007) pointed out that various guilds had distinct reactions to habitat disturbance, implying that trophic structure and, by extension, ecosystem function are influenced by human activity.

No ringed birds were rediscovered or spotted in a different forest. It was likely because there weren't enough individuals of each species banded in each forest for a significant probability of spotting dispersers among the various patches of forest. Birds living in the understory of tropical forests are said to be stationary and to avoid gaps and even forest removal (Van Houtan et al. 2007). (Pimm et al. 1993). It has been highlighted by Ehrlich and Raven (1969), Willis (1974), Terborgh et al. (1990), and Sodhi et al. (2004) that some tropical birds have a limited range, will not spread far from their natal territory and avoid unsuitable habitat because of physical or behavioral constraints. Consequently, most individuals bound in one fragment did not disseminate into another fragment.

It does not prove, however, that birds were not flying between the various fragments. Most migratory species, including the Crowned Hornbill, Trumpeter Hornbill, Retz's Helmet Shrike, and some other raptor species, could disperse and use the entire area for different survival needs. Furthermore, the three forests were connected and only separated by physical barriers of rivers and a creek which were not more than 30 m wide (Bennun and Howell 2002). It follows that the habitat characteristics of these forests may significantly impact the birds' survival in these pieces. Moreover, the tight closeness of fragments to one other would likely allow constant exchanges of highly mobile avifauna across the forests, even though avian dispersal was not demonstrated. Depending on the availability of resources, a bird may forage in one fragment and roost or nest in another. If destructive human activities degrade one or more forest pieces, the three sites should be viewed as a single habitat block whose biodiversity could be harmed.

Each of the three sections had around one-third of the known bird species. The overall consistency in vegetation structure between the three locations made this possible. Since Gandini and Mtswakara shared a similar composition of plants, the two places were home to the greatest number of avian relatives. Lower canopy cover (0-2m) and understory vegetation densities (1m and 2m) were comparable throughout the three sections. This scenario should have resulted in a minimum consistency between the three locations concerning species richness and abundance of the understory avifauna. However, it was not the case since these species were much more scarce in Mwache and Mtswakara than in Gandini. Understory birds were taken in equal numbers in both Mwache and Mtswakara, but this was still a far cry from the thousands brought in at Gandini. It suggests that the differences in understory abundances and species richness between the three sites are best explained by considering factors other than climate.

Quarrying, the enormous danger to birds, and other biodiversity in that forest may be to blame for the dearth of understory species in Mwache. At Mwache, 28 ha had been lost over 58 years (2008-1950), with an annual loss rate of 0.5 ha. It equals a total loss of about 28,000 square meters (1 ha = 10,000 $m^2$). Bird populations may have declined in Mwache due to forest removal, the loud noise caused by chemical explosions, and local people's frequent collecting of firewood and building poles. High demand for construction materials for roads and residences in and around Mombasa city and fast-expanding neighboring towns meant that quarrying operations would inevitably increase in the future unless immediate measures were made to regulate them (Miritini and Mazeras).

In addition, the boulders and other materials needed for the quarrying operations in the forest could be transported over the murram road, which was heavily used in Mwache. Near the road's midpoint, four quarries were spread out over the forest's middle, effectively severing Mwache into two sections. There are significant consequences for animal survival when human-built barriers like roads, trails, settlements, and other infrastructure break up a continuous habitat. Population density, range, and diversity are all influenced by fragmentation (Donovan and Flather, 2002). It is because fragmentation alters landscapes by destroying or separating previously continuous habitats into smaller, disconnected sections, both of which are dominated by humans. Individuals of certain species may have a decreased pairing rate (Brooker and Brooker 2003) if patches develop so widely apart that they are inaccessible to them.

Additionally, the availability of necessities like food may be impacted by fragmentation. Understory birds in Mwache likely suffered greatly due to the proximity of a busy road. So, the different numbers of birds found in the understorey at Mwache, Mtswakara, and Gandini could be attributed to the varying degrees of internal fragmentation and habitat disturbance at each location. Some birds, like the Blue-mantled Crested Flycatcher and the Red-tailed Ant Thrush, are only known from Gandini and are pretty reticent even when approached. It suggests that the understory habitat conditions in Gandini were more favorable for the survival of these species than in other forests. Even though Gandini and Mtswakara shared similar plant communities, their respective understory and canopy avifauna were strikingly unlike.

Gandini and Mtswakara shared similar vegetation structures; however, the understory avifauna was vastly different. There are practically identical canopy birds that could be found in both areas. However, variables responsible for the variation in understory avifauna diversity between the two sections of the forest are unknown. However, changes in logging levels (of different tree sizes), physical nature, and administrative organization

may all play a role. The peak of *Kaya* Gandini rose to an altitude of 10 and 200 meters above sea level, while the rest of the hill was quite gentle.

As you can see, this side of the mountain is right next to where lots of villagers are cutting down trees for use as poles and firewood. Because of its inaccessibility, most of this face, which accounts for around 10% of the entire primary habitat area, has remained relatively pristine from harmful human activity. Compared to Mtswakara, where the plane was smoother and the terrain was less challenging, Gandini was not an ideal location for harvesting forest products. As a result, Mtswakara may be the most popular option for villagers to harvest forest products at any particular moment.

One of the greatest risks to preserving these forests was harvesting firewood, construction poles, and lumber for personal use and commercial profit. Each forest had a unique pattern of tree removal (logging) and regrowth (standing live trees) of varying tree sizes. All other tree sizes (DBH >11 cm) were less likely to be cut down than young trees (DBH 5-10 cm). Perhaps it was due to the strong demand for young trees to build homes in the surrounding villages and provide rental properties in nearby cities like Miritini, Mazeras, and Mombasa City. It would also be simple to cut down some living trees for firewood. Unfortunately, there is a dense human population surrounding these three pieces, and they have been extracting building poles at an alarming rate. These young trees were large enough to represent the majority of plants that had already matured through the sapling stage and could eventually sustain a healthy forest. Thus, the careless cutting down of these young trees will eventually lead to the depletion of forest habitat. Young trees were logged at a higher rate in Mtswakara, followed by Gandini and Mwache. Since Mtswakara is the most sacred forest of the Duruma people, it was not subject to much human intrusion, as Waiyaki (1995) had previously discovered.

Before its reconstitution in 2007, the *Kaya* Mtswakara council of elders, responsible for overseeing the access and the license for exploitation of forest products, had been inactive for three years (2003-2006). As more people flooded into Mtswakara for firewood, building materials, and other forest goods, the once-protected forest likely degenerated into a "free for all" resource in its absence. In every forest studied, large trees (DBH >21lcm) were the least favored by loggers. Heavy machinery would be needed to remove these trees (big axes, saws, etc.). When the tree finally fell, it would leave a huge hole in the canopy. Loggers may have avoided massive trees because it would have been hard to hide the extraction process from nearby people who used several pathways to go through the forests.

A smaller percentage of trees of all sizes were cut down in Mwache compared to Mtswakara and Gandini. Possible explanations for the dissimilar logging practices in the *Kaya*s and the forest reserve include the presence of different management authorities. National Museums of Kenya's Coastal Forest Conservation Unit (CFCU) worked closely with the Duruma Council of elders to oversee the *Kaya*s. Each community maintained a council of elders and forest guards to keep the forested areas of their Kayas safe. Community forest guards were chosen to monitor the *Kaya* by the council of elders, although they were not actively involved in patrolling the forests daily. They only went on forest patrols when they had nothing more important to do. Some community watchmen had also begun stealing trees from both *Kaya*s instead of defending them as planned. Guarding the forests was a volunteer job for the community members, with payment in the form of tokens given to them whenever those community members paid for permission to cut down trees for use as building poles in *Kaya*'s homes. The guards may have been compelled to resort to tree poaching or give up their patrolling duties due to the absence of immediate economic rewards from the services they provided, poverty, and a lack of other practical alternatives for revenue-producing opportunities to support their families.

The community guards (in both *Kaya*s) chosen by the council of elders to monitor the forests for illicit activities failed to do their jobs effectively in 2007–2008. The Mtswakara council of elders was dissolved and reconstructed by the local chiefs without consulting all stakeholders (CFCU and local community), leading to the resignation of certain guards. Young trees in Mtswakara likely perished in large numbers due to this crisis. However, young trees were still logged in Gandini at a slower rate than in Mtswakara. One possible explanation is that the Gandini council of elders did a better job organizing and coordinating the patrols through the forest. Therefore, the council of elders' role in the conservation of the *Kaya*s, as had been done in past, despite diminishing owing to the disintegration of traditional ways of life Mijikendas, could still be effective in preserving these forests if all parties offered sufficient help. There was a rise in the loss of trees from the *Kaya*s in 2007-2008, although few locals were asking the council of elders in Gandini and Mtswakara for permission to harvest forest products. The populace had disregarded the elders' council. However, logging pressures in Mwache were much lower than in the *Kaya*s, most likely due to the presence of a KFS forest guard stationed in the reserve and actively engaged in forest patrols and apprehending tree poachers. Because of the forthcoming CBO's aid, tree poaching is likely to decrease.

Altogether, the three forests suffered a severe death toll in their tree populations. This is because dead standing and floor stems of various sizes, which firewood collectors seek out, were absent from the three forests. Since removing dead wood affects the density and distribution of cavity-nesting bird species, it damages forest biodiversity (Waiyaki 1995). Furthermore, it is because of the decrease in many holes and food (invertebrates which they feed on).

In conclusion, important as they already were, the three coastal forests remained crucial to protecting birds of prey. The greater diversity of forest specialists, generalists, understories, and internationally threatened East Africa Coastal Biome Species made *Kaya* Gandini more crucial for avian conservation. Comparatively fewer understory species were found in *Kaya* Mtswakara and Mwache Forest Reserve. The habitats of the three forest pieces were in

jeopardy due to unrestricted firewood collecting and extraction of building poles for sale and home use. The loss of biodiversity in Mwache can be attributed to the quarrying industry. This industry has been blamed for clearing vegetation and using explosives, both of which contribute to the constant roar of quarrying machines. As fewer and fewer individuals around the *Kaya*s forests respected and adhered to Duruma cultural norms, the council of elders responsible for their management began to lose power. As the number of people living in and around the *Kaya*s continued to grow, so did the demand for wood to satisfy domestic and commercial requirements, resulting in a never-ending struggle between community forest guards and illegal tree poachers. Due to there being only one forest guard, Mwache Forest was not very properly protected. Overall, there was a decreasing trend in the habitat quality of the three forests, which could result in a rapid decline in birds and other current biodiverse species if something isn't done soon. World Heritage Site status for the *Kaya*s brought international attention to the Gandini and Mtswakara and reaffirmed the significance of these locations in protecting biodiversity and Duruma traditional practices.

## REFERENCES


Adhikerana AS, Sugardjito J. 2010. Characterizing forest reduction in Ketapang District, West Kalimantan, Indonesia. Biodiversitas 11: 46-54. DOI: 10.13057/biodiv/d110110.

Axelrod D, Raven PH. 1978. Late cretaceous and tertiary vegetation history of Africa. In: Werger MJA (eds). Biogeography and Ecology of Southern Africa. The Hague: Junk Publications, Netherlands. DOI: 0.1007/978-94-009-9951-0_5.

Barlow J, Haugaasen T, Peres CA. 2002. Effects of ground fires on understorey bird assemblages in Amazonian forests. Biol Conserv 105: 157-169. DOI: 10.1016/S0006-3207(01)00177-X.

Bennun L, Dranzoa, C, Pomeroy D. 1996. The forest birds of Kenya and Uganda. JE Afr Nat Hist 85: 23-48. DOI: 10.2982/0012-8317(1996)85[23:TFBOKA]2.0.CO;2.

Bennun L, Howell K. 2002. Birds. In: Davies G (eds). African Forest Biodiversity; A Field Survey Manual for Vertebrates. Earthwatch Insititute, Cambridge, United Kingdom.

Bennun L, Waiyaki EM. 1992. Using birds to monitor environmental change in the Mau Forests. Research Report of the Center for Biodiversity, National Museums of Kenya. Ornithology Dept., Kenya.

Bennun L, Waiyaki EM. 1993. Using timed species counts (TSCs) to compare avifaunas in the Mau Forest, south-west Kenya. Proc VIII pan-Afr Orn Congr 366.

Bennun LA, Njoroge P. 1999. Important Bird Areas in Kenya. Nature, Nairobi, Kenya. DOI: 10.5962/bhl.title.87589.

Bennun LA, Waiyaki E. 1991. Arabuko-Sokoke Forest: Ornithological Survey. Unpublished Report. Centre for Biodiversity, National Museums of Kenya and KIFCON, Nairobi.

Bibby CJ, Martin J, Marsden S. 1998. Expedition Field techniques: Birds Surveys. Royal Geographic Society, London.

Blake JG, Loiselle BA. 2001. Variation in resource abundance affects capture rates of birds in three lowland habitats in Costa Rica. Auk 108: 114-130.

Brooker L, Brooker M. 2003. Dispersal and population dynamics of the blue- breasted fairy-wren *Malurus pulcherrinmus* in fragmented habitat in the western Austrian wheat belt. Wildl Res 29: 225-233. DOI: 10.1071/WR01113.

Burgess N, Butynski T, Gordon I, Sumbi P, Like Q, Watkin J. 2003. East Arc Mountains and Coastal Forest of Tanzania and Kenya Biodiversity Hotspots. Conservation International, Washington DC. USA.

Burgess ND, Clarke GP. 2000. The Coastal Forests of Eastern Africa. IUCN, Cambridge and Gland.

Donovan TM, Flather CH. 2002. Relationship among North American songbirds trends, habitat fragmentation, and landscape occupancy. Ecol Appl 12: 363-374. DOI: 10.1890/1051-0761(2002)012[0364:RANAST]2.0.CO;2.

Ehrlich PR, Raven PH. 1969. Differentiation of populations. Science 165: 1228-1232. DOI: 10.1126/science.165.3899.1228.

Fanshawe JH. 1993. The Effects of Selective Logging on the Bird Community of Arabuko-Sokoke Forest, Kenya. [Unpublished PhD Thesis]. University of Oxford, UK.

Frost A, King C. 2003. Gathering indigenous knowledge as a tool for rural research, development and extension: Case study on rodent management in Cambodia. In: Singleton G, Hinds L, Krebs C, Spratt D (eds). Rats, Mice and People: Rodent Biology and Management. Australian Centre for International Agricultural Research, Canberra.

Furness RW, Greenwood JJD. 1993. Birds as Monitors of Environmental Change. Chapman and Hall, London. DOI: 10.1007/978-94-015-1322-7.

Gray MA, Baldauf SL, Mayhew PJ, Hill JK. 2007. The response of avian feeding guilds to tropical forest disturbance. Conserv Biol 21: 133-141. DOI: 10.1111/j.1523-1739.2006.00557.x.

Hamilton AC. 1981. The Quaternary History of African Forests: Its Relevance to Conservation. ICBP, Cambridge. DOI: 10.1111/j.1365-2028.1981.tb00647.x.

Howell KM. 1981. Pugu Forest Reserve: Biological values and development. Afr J Ecol 19: 73-81. DOI: 10.1111/j.1365-2028.1981.tb00653.x.

Ityeng D, Kapua I, Maingi P, District Steering Committee. 2008. Kwale District Long grains Assessment Report 2008. Kwale District 2008 Long rains Assessment Report-28"" July-2™ August 2008. Kwale District, Mombasa.

Laurence SW, Stoupffer PC, Laurence WF. 2004. Effects of road clearings on movement patterns of understorey rainforest birds in Central Amazonia. Conserv Biol 18 (4): 1099-1109. DOI: 10.1111/j.1523-1739.2004.00268.x.

Levey DJ. 1988. Tropical wet forest treefall gaps and distributions of understorey birds and plants. Ecology 69: 1076-1089. DOI: 10.2307/1941263.

Lowler HM, Cohen L. 1990. Practical Statistics for Field Biology. John Wiley and Sons, New York, USA.

Moegenburg SM, Levey DJ. 2003. Do frugivores respond to fruit harvest? An experimental study of short-term responses. Ecology 84: 2600-2612. DOI: 10.1890/02-0063.

Musila SN, Ng'weno F, Matiku P, Bennun L, Kanyanya E, Mulwa R, Mwema M, Kiragu A, Siele J, Musina J, Buckley P, Machekele J, Njehia S. 2005. Important Bird Areas (IBAs) Status and Trends Report 2005. [Report]. Nature Kenya, Nairobi.

Newmark WD. 1991. Tropical forest fragmentation and local extinction of understory birds in the eastern Usambara Mountains, Tanzania. Conserv Biol 5: 67-78. DOI: 10.1111/j.1523-1739.1991.tb00389.x.

Pimm SL, Diamond JM, Reed TM, Russell GJ, Verner J. 1993. Times to extinction for small populations of large birds. Proc Natl Acad Sci USA 90: 10871-10875. DOI: 10.1073/pnas.90.22.10871.

Pomeroy DE, Tengecho B. 1986. A method of analyzing bird distributions. Afr J Ecol 24: 243-253. DOI: 10.1111/j.1365-2028.1986.tb00368.x.

Robertson SA, Luke WRQ. 1993. Kenya Coastal Forests: The Report of NMK/WWF Coast Forest Survey. WWF, Nairobi.

Rosenberg KV. 1993. Diet selection in Amazonian antwrens-consequences of substrate specialization. Auk 110: 361-375.

Sodhi NS, Liow LH, Bazzaz FA. 2004. Avian extinctions from tropical and subtropical forests. Ann Rev Ecol Evol Syst 35: 323-345. DOI: 10.1146/annurev.ecolsys.35.112202.130209.

Terborgh J, Robinson SK, Parker TA, Munn CA, Pierpont N. 1990. Structure and organization of an Amazonian forest bird community. Ecol Monogr 60: 213-238. DOI: 10.2307/1943045.

TuTiempo.net. 2008. Historical Weather: Mombasa, Kenya. January 2008.

Van Houtan KS, Pimm SL, Halley JM, Bierregaard Jr RO, Lovejoy TE. 2007. Dispersal of Amazonian birds in continuous and fragmented forest. Conserv Biol 10: 219-229. DOI: 10.1111/j.1461-0248.2007.01004.x.

Waiyaki E. 1995. Effects of Forest Fragmentation, Isolation, and Structure on the Richness and Abundance of Bird Communities in Major Coastal Forests of South coast, Kenya. [Unpublished MSc. Thesis]. University Kent, Canterbury.

Willis EO. 1974. Populations and local extinctions of birds on Barro Colorado Island, Panama. Ecol Monogr 44: 153-169. DOI: 10.2307/1942309.

Zimmerman DA, Turner DA, Pearson DJ. 1996. Birds of Kenya and Northern Tanzania. Russel Friedman Books, Halfway House.