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NAIROBI-NAKURU-MAU SUMMIT HIGHWAY PROJECT

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

KENYA - APPENDICES 6-13 TO 6-17

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APPENDIX

6-13 *LAND USE AND LAND USE CHANGE ANALYSIS*

Nairobi-Nakuru-Mau Summit Highway Project
Biodiversity synthesis studies for the ESIA
Republic of Kenya

LAND USE AND LAND USE CHANGE ANALYSIS
FINAL REPORT

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1. CONTEXT FOR THE WORK

WSP Canada has been commissioned by Rift Valley Highway Limited (RVHL) to complete the Environmental and Social Impact Assessment (ESIA) for the Nairobi-Nakuru-Mau Summit Highway Project. The ESIA is undertaken in order to anticipate and identify adverse environmental and social risks and develop robust mitigation measures through the application of mitigation hierarchy.

As part of the WSP Canada consortium in the proposal made to RVHL, Flora Fauna & Man Ecological Services Ltd (FFMES) has been tasked to undertake the biodiversity surveys along the proposed road alignment as well as some of the synthesis work on biodiversity in preparation for impact assessment. While baseline work spanned Vegetation (including woody biomass), Mammals (including small terrestrial mammals), Avifauna, Herpetofauna (Reptiles & Amphibians) and Freshwater ecology, the synthesis work spans:

- Land use and land use change analysis,
- Standardised biodiversity sensitivity analysis,
- IFC habitat classification.

The present document provides an outline of the work undertaken with respect to:

- Land use and land use change analysis

For this scope of work, FFMES was requested to develop a map of the landscape of concern for the Kenya project. The scope of the work takes the form of a land use and land use change analysis (LULUCA) spanning three reference years (the years 2000, 2010 and 2020). The present analysis provides an overview of the current land use and land cover for the study area as well as the grounding of the current situation within the context of the land use and land cover since the year 2000. Images were analysed in 10-year increments to provide a broad outline of the evolution of the landscape over the past 20 years.

2. INTRODUCTION

Knowledge of a landscape, its present state and past changes is important for project development. It provides a key base from which to predict change post project development and assess changes in relation to project development (Slootweg *et al*., 2010). Satellite imagery is essential in this assessment as it allows for an understanding of the landscape processes and the level of degradation of the landscape prior to project commencement.

An objective overview of a landscape in both its present and historical states provides a base from which the true impact of a project's development can be assessed. It also offers a standpoint which can be referred to should conflicts regarding landscape alteration arise. The latter is especially important to ensure a developer is clearly allocated responsibility for the impacts it has triggered and associated changes to pre-existing trends but is not made responsible for the pre-existing impacts and trends (Slootweg *et al*., 2010). In addition, this provides project developers a means of identifying any areas of degradation that their project or the project's impact mitigation strategies can improve upon and consider positive impacts. Furthermore, this analysis is required to answer the IFC PS6's question regarding the duration of habitat degradation needed for a habitat to be considered modified rather than natural (IFC, 2019). Presently, habitats are considered modified if they have existed in their current state for an extended period of time (+/- 20 years) and have a low likelihood of returning to their natural state based on current land use of the indications of a degradation assessment.

The present report is a desktop-based evaluation of the land use change between the years 2000 and 2020, making use of a number of key land use classes which could be tracked over this 20-year period. Freely available coarse scale satellite imagery was used (LANDSAT 7 and 8 and well as Sentinel images). The analysis used three reference years (2000, 2010 and 2020) and provided an overview of change between each of these 10-year periods and the 20 years between 2000 and 2020. This evaluation was performed using available imagery with standard computer based analytical processes guided by expert review for broad land cover classes definition.

This study provides context for the project which, depending on management decisions, may exacerbate or mitigate past trends.

3. STUDY AREA

The study area corresponds to the project's Biodiversity Regional Assessment Area, and covers 1,378,329 ha and spans almost 200 km from Nairobi to Mau Summit, encompassing the cities of Nakuru and Naivasha. The analysis covered the entire area and provided a coarse landscape overview.

The size of the study area allowed for automated "de-clouding" procedures to function optimally using machine learning processes. The landscape context is thus expected to be more robust than if it had been restricted to a smaller area where automated analyses may have failed to function optimally.

4. METHODS – LAND USE CHANGE ANALYSIS

4.1. IMAGE SELECTION AND PROCESSING

Images were selected which were at least 60% cloud free (less than 40% cloud cover at the scale of the image tile), but preferably higher. Satellite images which are completely cloud free are rare for the African continent and thus it becomes necessary to create some images from a composite mosaic of such cloud free images. This mosaic allows land use and land use change analysis to be performed. The study area is shown in Figure 1.

TNTMips image processing software was used to perform the analysis. Semi-automatic digital feature mapping aided by known area training was used to map transformation on individual images covering the land use change analysis study area. The software details are:

- TNTMips Pro 2012
- Issue date: 27th November 2013
- Build Platform: Windows 64-bit
- Copyright © 1988-2018 MicroImages, Inc.
- www.microimages.com

The land cover use mapping was done for three "constructed" reference dates (2000, 2010 and 2020), which represented two periods (2000 to 2010 and 2010 to 2020) of analysis. The satellite images used in the mapping process are summarised in Table 1.

Table 1: Listing of satellite images used for the analytical process.

Sensor	Path and row	Image date	Cloud cover (%)	Quality	Comments	SLC-off	Burn Scars (%)
Landsat 7	168 60	2000 02 05	1	Good			0
Landsat 7	168 61	2000 02 21	0	Good			0
Landsat 7	169 60	2000 01 27	0	Good			0
Landsat 7	169 60	2000 02 12	0	Good			0
Landsat 7	168 60	2009 01 12	7	Medium	GLCS gapfilled	x	0
Landsat 7	168 61	2010 12 17	1	Medium	GLCS gapfilled	x	0
Landsat 5	169 60	2010 01 30	6	Good	GLCS		0
Landsat 5	169 61	2010 01 30	5	Medium	GLCS		0
Landsat 8	168 60	2020 02 20	1	Good			0
Landsat 8	168 61	2020 02 20	1	Good			0
Landsat 8	169 60	2020 02 11	2	Good			0
Landsat 8	169 61	2020 02 11	0	Good			0

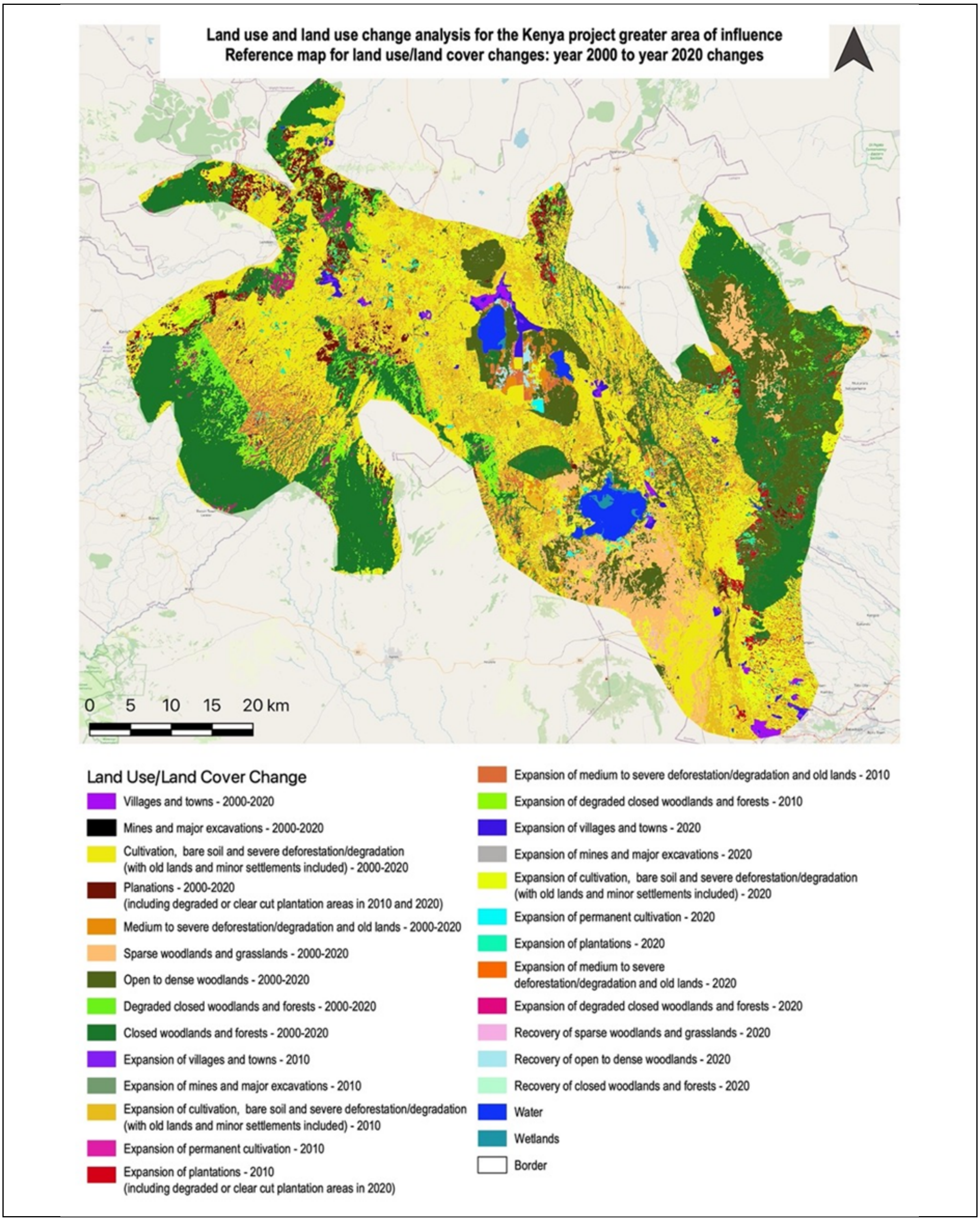

Figure 1: The study area for the land use change analysis. The present map highlights the changes in land use considered to have occurred between 2000 and 2020.

The following projections were used for the images and associated maps:

- Coordinate Reference System:
- Name: WGS84/ UTM 30 North
- Projection: UTM zone 30N
- Method: Transverse Mercator
- Latitude of natural origin: N 0 00 00.000
- Longitude of natural origin: E 33 00 00.000
- Scale factor at natural origin: 0.9996
- False easting: 500000m
- False northing: 0m
- Datum: World Geodetic System 1984 (WGS84)
- Type: Geodetic
- Epoch: 1984
- Ellipsoid: WGS 1984
- Semi-major axis 6378137
- Inverse flattening: 298.257224
- Prime Meridian: Greenwich
- Valid Area
- World
- Coordinate System
- Type: Projected
- Axis 1: Easting
- Unit: meter
- Symbol: E
- Axis 2: Northing
- Unit: meter
- Symbol: N

An initial evaluation of land cover and land use in the study area at present was obtained from high resolution Google Earth imagery. Manmade features identified from the 2018 imagery were used as a guideline for the features observed on the images from 2000 and 2010.

All Landsat images were resampled to 10 m to be consistent with the 10 m ground resolution imagery of Sentinel (Mayaux *et al*., 2013). ISODATA classifications (100-150 classes) were done on all the 10 m resampled imagery. An interactive feature mapping process was then followed by lumping classes to represent land cover use classes as defined from the training area represented by the project area on the 2020 reference year image. The image analyst was set to constantly use multiple image dates and the reference training areas on high resolution Google Earth imagery to map these classes from the medium resolution imagery. Multi-date imagery provided better contrast between manmade features and natural vegetation. All villages and towns were digitised by hand by an image analyst, through localities data for Kenya and through direct mapping using recent high-resolution Google Earth support imagery of the study area. The hand digitised features were then pasted into the ISODATA and feature mapping products.

The structural vegetation mapping was done on the PAN band of Landsat and bands 2, 3 and 4 of the Sentinel images. A local adaptive filter was applied to remove any localised darkening effect of shadows and soil colour prior to the mapping of vegetation structure. Interactive scaling was used by an image analyst to map the vegetation structure by constantly comparing the scaling to high resolution Google Earth images. The vegetation structural mapping was however only done for the 2020 reference year as the older reference years had insufficient resolution to be used for this purpose with a comparable accuracy level.

Combining land cover use maps from 2000 and 2010 with the 2020 land use cover map and analysing with a Boolean algebra script provided land cover use change mapping. The vegetation structure was also added with the script for all the natural vegetation areas that had no man-made features.

The following analyses were subsequently undertaken:

1) Land use/land cover analysis – this analysis summarises the land use and land cover interpreted from the images for the specified period (i.e. 2000, 2010 or 2020). Older images limit the analysis due to their resolution and increasing resolution allows for more defined and detailed land use class information. However, for chronological continuity, the land use classes provided for the year 2000 are considered the limiting factor and need to be used for analysis of all subsequent reference years. This is despite the fact that 2020 image analysis could offer far more land use classes than 2000 imagery. This analysis was performed for the entire study area and the four sectors.
2) Land use/land cover change analysis – this analysis evaluates the changes between land use and land cover between the years in focus. All land use and land cover classes are used and any new land use classes that were unrecognised in earlier images are, if relevant added to the "change" considerations. This analysis was performed for the entire study area and the four sectors.

The following land use classes were specified for analysis:

- 2000 image

1) Villages and towns
2) Mines and major excavations
3) Cultivation and severe deforestation/degradation (with old lands and minor settlements included)
4) Permanent cultivation (greenhouses)
5) Plantations
6) Medium to severe deforestation/degradation and old lands
7) Sparse woodlands and grasslands
8) Open to dense woodlands
9) Degraded closed woodlands and forests
10) Closed woodlands and forests
11) Water
12) Wetlands

- The land use classes were carried over for each of the subsequent reference years images of 2010 and 2020.

The results obtained are broad scale in nature and are based upon coarse grain resolution, yet this was considered sufficient to identify major changes in land use and land cover. The land use and land cover classes are broad yet provide a good level of reliability for this analysis.

4.2. EVALUATION OF SELECTION FACTORS

To advance analysis and assist in identification of the drivers of future change the underlying factors of land use and land cover change was analysed. In many cases the underlying factor of land use change is human settlements or road presence (Van Rooyen *et al*., 2018). This has been shown in previous land use and land use change analyses to drive the development of agricultural land (Mayaux *et al*., 2013). However, the relationship between these factors is complex and often human presence can cause some land use and land cover types to expand or contract in the landscape. For each year studied, using the Euclidean Distance Analysis function of ArcGIS, the distance between the polygons noted for the land use or land cover class investigated and the nearest village/town were identified, and the area of each polygon was specified. This was repeated to include an analysis of the distance between polygons for each land use or land cover class and the nearest road in the landscape. The maximum distance measure from any given year analysed was summarised as five equal bins of distance class for further analysis. Then, for each reference year, a further summary analysis was performed to define; the total polygon area (in ha), mean polygon area (in ha), maximum polygon area (in ha) and minimum polygon area (in ha) for the land use/land cover classes 3 to 6 extents identified within each of the five distance classes defined. The sum value is expected to highlight the overall representation of the land use/land cover class within that distance class. The mean value is expected to represent the “typical” area of a patch for the specified land use/land cover class. The maximum value is expected to represent the single biggest area noted for the year specified in the distance class, while the minimum value is the inverse of the latter. The analysis using Euclidean distance as performed here therefore highlights the envelope of influence of the villages or roads and also illustrates the relative proximity of villages or roads to each other through the nature of the maximum distance classes observed.

For each of the parameters (sum, mean, maximum and minimum) a repeated measure ANOVA using nonparametric assumptions (Friedman test) was used to evaluate whether significant differences appeared between the reference years (using a Dunn’s post-test) (Motulsky and Christopoulos, 2003).

5. LIMITATIONS

This model only provides coarse scale information regarding “major” land use/land cover forms. This is due to the limitations associated with freely available historical satellite imagery and continuous problems relating to cloud cover in equatorial African countries. As such, this analysis provides information regarding the major determinants of land use and a context around which land use change can be assessed. Without field verification, which could be used to define land use and land cover, this work cannot be further refined.

6. RESULTS

6.1. LAND USE AND LAND USE CHANGE

6.1.1. Year 2000

The land use and land cover mosaic of the year 2000 served as the basis against which future changes in land use and land cover were assessed. The land use and cover in 2000 showed well established levels of human influence with cultivated and severely degraded land covering 28.61% of the area. Natural landscapes, those labelled as 'closed woodlands and forests', were present in 2000 and covered over 25% of the area, which further supports the suggestion that the study area was already well transformed by this first reference year. There is also an indication of transitional landscape presence with open to dense woodlands covering 23.19% of the landscape. In 2000 there was no evidence of industrial scale cultivation and little evidence of mining and major excavations. Clear evidence of human settlements was noted as this Land Use Class covered 5,003 ha (Table 2, Figure 2).

Table 2: Overview of land use and land cover for year 2000.

No	Class	%	Area (ha)
1	Villages and towns	0.36	5,003
2	Mines and major excavations	0.00	56
3	Cultivation and severe deforestation/degradation (with old lands and minor settlements included)	28.61	394,297
4	Permanent cultivation (greenhouses)	0.00	0
5	Plantations	2.49	34,321
6	Medium to severe deforestation/degradation and old lands	8.84	121,900
7	Sparse woodlands and grasslands	6.08	83,732
8	Open to dense woodlands	23.19	319,605
9	Degraded closed woodlands and forests	2.86	39,386
10	Closed woodlands and forests	25.69	354,200
11	Water	1.68	23,141
12	Wetlands	0.20	2,689
	Total	**100.00**	**1,378,329**

6.1.2. Year 2010

Between 2000 and 2010, there is a clear growth in cultivation and severe deforestation with a 29.70% increase in this Land Use Class in the study area over the 10-year period. Such growth is reflected partially in a reduction in the cover of closed woodlands and forests. Indeed, this Land Use Class reduced from covering 25.69% of the study area in 2000 to covering 21.99% in 2010. There is a slight growth in the mines and major excavations Land Use Class and there is an indication of the emergence of permanent cultivation (greenhouses). This Land Use Class grew by 188 ha in the 10-year period since 2000. While there is clear evidence of significant human-driven landscape transformation, the total land covered by villages and towns remains limited in the landscape, covering 6,894 ha or 0.50% of the study area (Table 3, Figure 3).

Table 3: Overview of land use and land cover for the year 2010.

No	Class	%	Area (ha)
1	Villages and towns	0.50	6,894
2	Mines and major excavations	0.01	83
3	Cultivation and severe deforestation/degradation (with old lands and minor settlements included)	37.13	511,750
4	Permanent cultivation (green houses)	0.01	188
5	Plantations	2.74	37,708
6	Medium to severe deforestation/degradation and old lands	12.41	170,989
7	Sparse woodlands and grasslands	4.87	67,165
8	Open to dense woodlands	14.39	198,330
9	Degraded closed woodlands and forests	4.09	56,356
10	Closed woodlands and forests	21.99	303,062
11	Water	1.68	23,199
12	Wetlands	0.19	2,607
	Total	**100.00**	**1,378,329**

6.1.3. Year 2020

In 2020 the trends observed in both 2000 and 2010 appear to continue. Cultivated and severely degraded land continued to grow within the study area. This Land Use Class grew by 25.40% between 2010 and 2020 and by 62.80% in the 20-year study period. Most likely as a consequence of this, the presence of closed woodlands and forests continued its downward trajectory in the study area. This Land Use Class was reduced from 354,200 ha in 2000 to 285,600 ha in 2020, a 19.30% reduction overall. Similar reductions are also seen in the cover of open to dense woodlands. Plantations grew slightly between 2010 and 2020, but a drastic growth is observed in the expansion of permanent cultivation (greenhouses). In 2000 this Land Use Class covered 0 ha, in 2020 it covered 3,375 ha. Between 2010 and 2020 this Land Use Class grew by 1,695.00%. Mining and major excavations also saw a 487.90% growth between 2010 and 2020. Such developments show a growing human impact on the landscape and this is apparent through the growth in villages and towns over the 20-year study period. In 2000, villages and towns covered 5,003 ha (0.36% of the landscape), in 2020 this Land Use Class grew to cover 16,077 ha of the study area (1.17% of the landscape), a growth of 221.40% (Table 4, Figure 4).

Table 4: Overview of land use and land cover for the year 2020.

No	Class	%	Area (ha)
1	Villages and towns	1.17	16,077
2	Mines and major excavations	0.04	488
3	Cultivation and severe deforestation/degradation (with old lands and minor settlements included)	46.57	641,890
4	Permanent cultivation (green houses)	0.25	3,375
5	Plantations	3.09	42,546
6	Medium to severe deforestation/degradation and old lands	4.15	57,226
7	Sparse woodlands and grasslands	4.44	61,149
8	Open to dense woodlands	12.76	175,928
9	Degraded closed woodlands and forests	4.95	68,265
10	Closed woodlands and forests	20.72	285,600
11	Water	1.67	23,079
12	Wetlands	0.20	2,707
	Total	**100.00**	**1,378,329**

6.1.4. Land Use Change

Land use change analysis between the image mosaics of 2000 and 2020 shows that the majority of the landscape in the study area has been transformed, with a significant emphasis on the growth of cultivated and severely degraded land, a precursor for the development of which is severe deforestation. There has been little expansion of natural landscapes over the 20-year period and indeed little recovery of these landscapes. Open to dense woodlands saw a slight recovery, however closed woodlands and forests saw very little recovery. All the changes observed over the 20-year period indicate growing human pressure on the landscape and anthropogenically-driven landscape transformation. Reducing forest cover is of concern for biodiversity conservation and ecosystem service preservation. However, wetlands, which globally are key habitats for biodiversity, remained relatively stable in the landscape between 2000 and 2020 (Table 5, Figure 1).

Table 5: Overview of land use change between the 2000 and 2020 image groups analysed.

No	Class	%	Area (ha)
1	Villages and towns - 2000 - 2020	0.36	4,938
2	Mines and major excavations - 2000 - 2020	0.00	55
3	Cultivation, bare soil and severe deforestation/degradation (with old lands and minor settlements included) - 2000 - 2020	20.80	286,746
4	Plantations - 2000 - 2020 (including degraded or clear cut plantation areas in 2010 and 2020)	2.56	35,246
5	Medium to severe deforestation/degradation and old lands - 2000 - 2020	2.48	34,189
6	Sparse woodlands and grasslands - 2000 - 2020	4.60	63,384
7	Open to dense woodlands - 2000 - 2020	13.66	188,226
8	Degraded closed woodlands and forests - 2000 - 2020	2.64	36,358
9	Closed woodlands and forests - 2000 - 2020	22.25	306,622
10	Expansion of villages and towns - 2010	0.15	2,006
11	Expansion of mines and major excavations - 2010	0.00	45
12	Expansion of cultivation, bare soil and severe deforestation/degradation (with old lands and minor settlements included) - 2010	13.04	179,755
13	Expansion of permanent cultivation - 2010	0.02	239
14	Expansion of plantations - 2010 (including degraded or clear cut plantation areas in 2020)	1.35	18,620
15	Expansion of medium to severe deforestation/degradation and old lands -2010	2.81	38,657
16	Expansion of degraded closed woodlands and forests - 2010	1.38	18,971
17	Expansion of villages and towns - 2020	0.70	9,595
18	Expansion of mines and major excavations - 2020	0.03	392
19	Expansion of cultivation, bare soil and severe deforestation/degradation (with old lands and minor settlements included) - 2020	7.43	102,460
20	Expansion of permanent cultivation - 2020	0.25	3,379
21	Expansion of plantations - 2020	0.51	7,052
22	Expansion of medium to severe deforestation/degradation and old lands - 2020	0.08	1,095
23	Expansion of degraded closed woodlands and forests - 2020	0.69	9,475
24	Recovery of sparse woodlands and grasslands - 2020	0.10	1,416
25	Recovery of open to dense woodlands - 2020	0.25	3,481
26	Recovery of closed woodlands and forests - 2020	0.01	76
27	Water	1.69	23,225
28	Wetlands	0.19	2,630
	Total	**100.00**	**1,378,329**

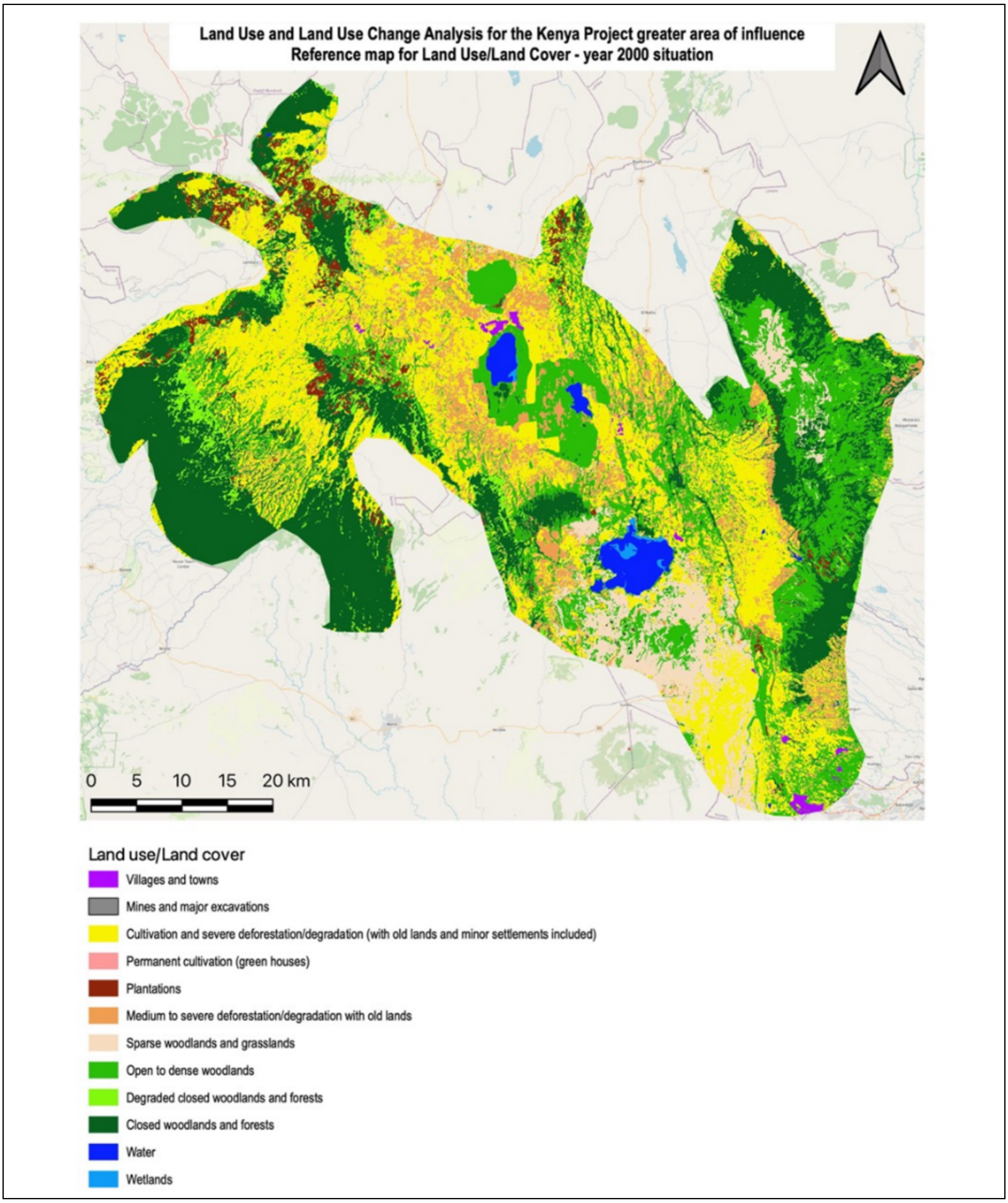

Figure 2: The study area for the Land Use analysis as perceived for the 2000 reference year.

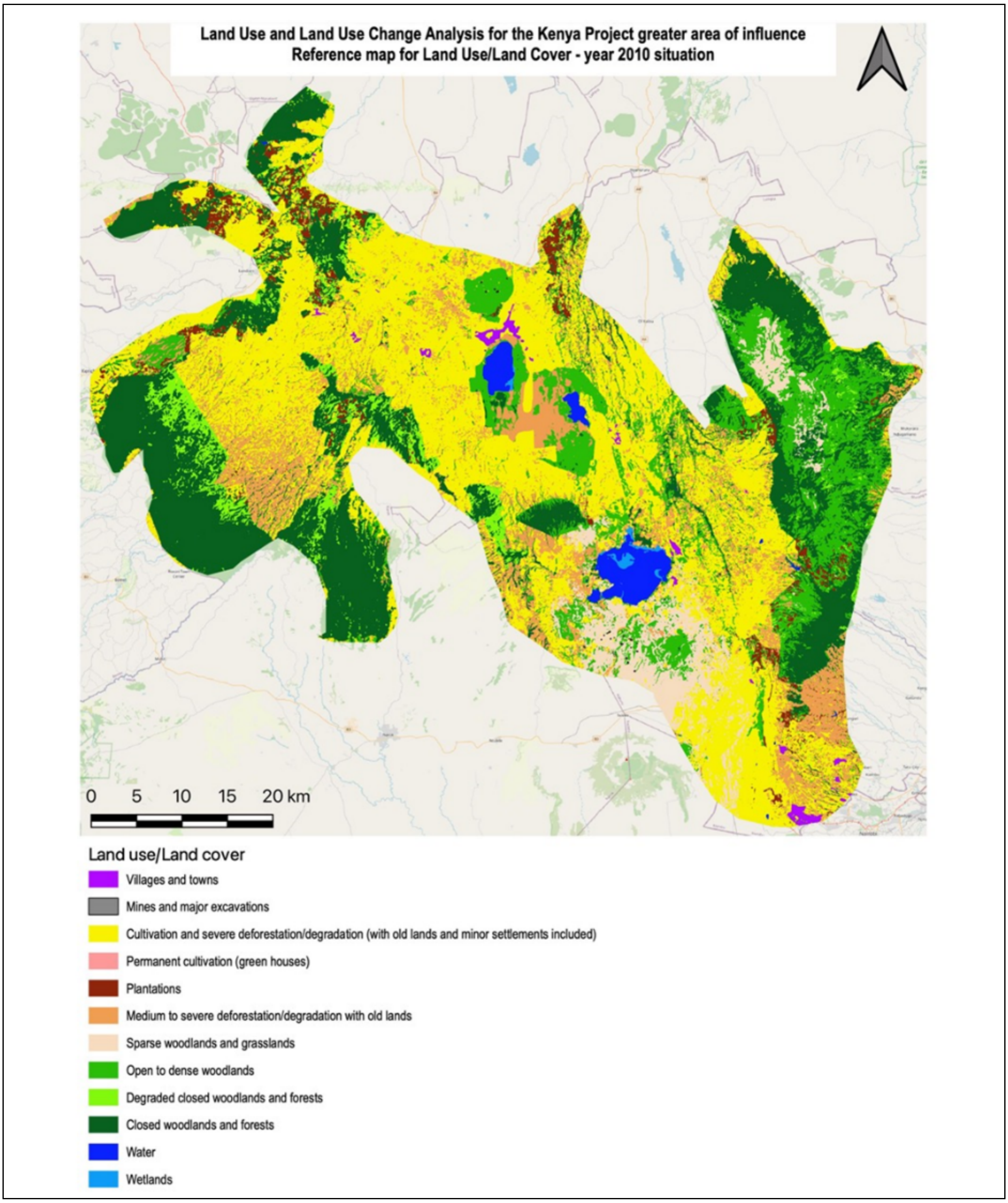

Figure 3: The study area for the Land Use analysis as perceived for the 2010 reference year.

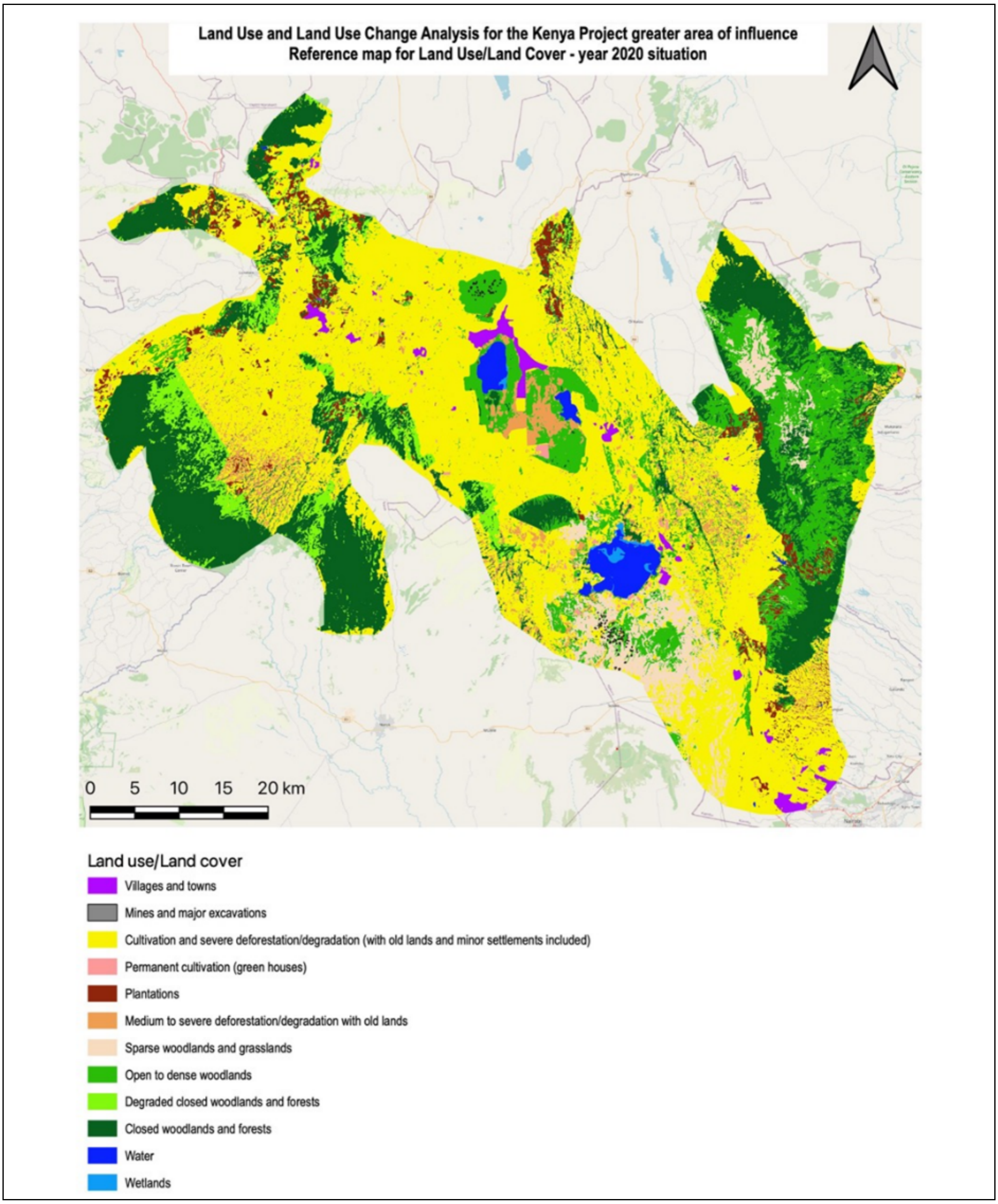

Figure 4: The study area for the Land Use analysis as perceived for the 2020 reference year.

7. EVALUATION OF SELECTION FACTORS

7.1. LAND USE CLASS 3 (Cultivation, bare soil and severe deforestation/degradation (with old lands and minor settlements included))

7.1.1. Distance from settlements

Between each reference year there is a clear and steady growth in the total land used for cultivation or land which has suffered from severe deforestation. This is shown in all parameters measured, but is most notable in the maximum size of a polygon of this Land Use Class recorded for each distance category. This parameter increased by 184.2% between 2000 and 2010 and then by 98.1% between 2010 and 2020, resulting in the largest polygon of this Land Use Class growing from 94,947 ha in 2000 to 562,623 ha in 2020 (no significance, Friedman statistic 2.8, p = 0.25). Such a growth is aligned with a general reduction in the total number of polygons analysed for the Land Use Class in each reference year (no significance, Friedman statistic = 2.8, p value = 0.25). This suggests an amalgamation of units of land covered by cultivation, bare soil and severe deforestation and potential destruction of other, perhaps more natural Land Use Classes. There is also a strong trend of the largest units of this Land Use Class being located between 3.5 and 4.5 km away from settlements. This shows the strong link between human presence, significant deforestation and the establishment of agricultural practices in the study area (Table 6).

Table 6: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 3 in relation to distance from settlements in the study area

Year	Distance category	Ranging from (in m)	To (in m)	Sum of area (ha)	Mean area (in ha)	Max area (in ha)	Min area (in ha)	Count of polygons analysed
2000	1	0	4,265	340,204	81.4	94,947.6	0.5	4,179
2000	2	4,265	8,530	40,999	14.6	4,870.0	0.4	2,808
2000	3	8,530	12,794	9,336	11.3	366.0	0.6	826
2000	4	12,794	17,059	3,110	15.1	505.4	0.7	206
2000	5	17,059	21,324	646	29.4	451.4	0.9	22
			Sum or means value	394,296	30.4	20,228.1	0.6	8,041
2010	1	0	4,166	467,771	188.8	282,136.2	0.5	2,478
2010	2	4,166	8,333	33,549	18.0	3,358.6	0.5	1,860
2010	3	8,333	12,499	7,593	17.4	1,267.1	0.7	437
2010	4	12,499	16,665	2,197	14.3	289.7	0.7	154
2010	5	16,665	20,832	638	24.5	384.5	0.7	26
			Sum or means value	511,749	52.6	57,487.2	0.6	4,955
			Change from prev. ref. year (%)	29.8	73.3	184.2	4.6	
2020	1	0	3,830	605,331	601.7	562,623.2	0.4	1,006
2020	2	3,830	7,660	21,833	21.1	2,852.3	0.4	1,036
2020	3	7,660	11,490	8,849	16.8	1,930.1	0.3	527
2020	4	11,490	15,320	4,425	26.2	1,526.7	0.4	169
2020	5	15,320	19,151	1,477	35.2	619.5	0.6	42
			Sum or means value	641,916	140.2	113,910.4	0.4	2,780
			Change from prev. Ref. year (in %)	25.4	166.5	98.1	-35.8	

7.1.2. Distance from roads

In a demonstration of the connected nature of the study area, cultivated land or land which has been subject to severe deforestation was located no further than +/-14 km from a road in 2000 and 2010. This distance reduced to a maximum of +/-11 km in 2020, showing the development of roads in the region. In a similar manner to the relationship between distance to settlements and Land Use Class 3 there is a strong indication of growing cultivation and increasing deforestation in the area. Notable in this analysis is the reduction in the minimum polygon size in each distance category. In comparison to 2010, a significant reduction in the minimum polygon size in 2020 is noted for all distance categories (Friedman statistic = 7.6, p = 0.02), further supporting the suggestion of merging cultivated plots and deforested land (Table 7).

Table 7: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 3 in relation to distance from roads in the study area

Year	Distance category	Ranging from (in m)	To (in m)	Sum of area (ha)	Mean area (in ha)	Max area (in ha)	Min area (in ha)	Count of polygons analysed
2000	1	0	2,818	359,145	63.6	94,947.6	0.5	5645
2000	2	2,818	5,635	27,289	17.3	4,870.0	0.5	1578
2000	3	5,635	8,453	5,819	10.5	271.8	0.4	553
2000	4	8,453	11,270	1,841	8.1	201.2	0.7	227
2000	5	11,270	14,088	202	5.3	49.8	0.8	38
			Sum or means value	394,296	21.0	20,068.1	0.6	8,041
2010	1	0	2,838	485,863	139.9	282,136.2	0.5	3,473
2010	2	2,838	5,676	19,424	18.8	2,421.2	0.7	1033
2010	3	5,676	8,515	5,149	16.5	433.4	0.5	312
2010	4	8,515	11,353	1,236	10.3	238.4	0.7	120
2010	5	11,353	14,191	78	4.6	25.9	0.8	17
			Sum or means value	511,749	38.0	57,051.0	0.7	4,955
			Change from prev. Ref. year (in %)	29.8	81.3	184.3	15.0	
2020	1	0	2,201	623,077	401.7	562,623.2	0.3	1,551
2020	2	2,201	4,401	12,085	16.2	2,852.3	0.5	744
2020	3	4,401	6,602	4,836	14.0	574.5	0.4	345
2020	4	6,602	8,802	1,533	13.4	281.4	0.3	114
2020	5	8,802	11,003	384	14.8	288.4	0.4	26
			Sum or means value	641,916	92.0	113,324.0	0.4	2,780
			Change from prev. Ref. year (in %)	25.4	142.1	98.6	-43.0	

7.2. LAND USE CLASS 4 (Permanent cultivation (greenhouses))

7.2.1. Distance from settlements

Land Use Class 4, permanently cultivated land or that covered by green houses, was not present in 2000. There is a clear establishment of this Land Use Class in 2010 and strong growth in 2020. In 2010 this Land Use Class was found no further than 5.5 km away from settlements, however this distance increased to just over 7.1 km in 2020. The growth in this industry is apparent in all parameters measured. Most notable are the significant growth in the total area covered by this land use increasing by 1,694.6% between 2010 and 2020 (Friedman statistic = 5, p value = 0.02). The largest sum of land used for permanent cultivation is consistently located within the 4th distance category. This suggests that there is a purposeful establishment of permanent cultivation on plots of land away from settlements, perhaps indicating the industrial nature of this Land Use Class and the need for large and continuous units of land for its development (Table 8).

Table 8: Overview of land use change between 2010 and 2020 image groups analysed for Land Use Class 4 in relation to distance from settlements in the study area.

Year	Distance category	Ranging from (in m)	To (in m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2010	1	0	1,090	2	2.1	2.1	2.1	1
2010	2	1,090	2,181	42	10.4	21.5	3.6	4
2010	3	2,181	3,271	10	9.9	9.9	9.9	1
2010	4	3,271	4,362	115	19.2	44.2	3.2	6
2010	5	4,362	5,452	19	6.5	16.0	0.8	3
			Sum or means value	188	9.6	18.7	3.9	15
2020	1	0	1,420	526	22.9	108.3	0.8	23
2020	2	1,420	2,841	417	23.2	58.2	1.7	18
2020	3	2,841	4,261	1,045	45.4	173.6	1.6	23
2020	4	4,261	5,682	1,167	64.8	746.7	1.2	18
2020	5	5,682	7,102	220	15.7	63.5	1.0	14
			Sum or means value	3,375	34.4	230.1	1.3	96
			Change from prev. Ref. year (in %)	1,694.6	258.2	1,129.3	-67.5	

7.2.2. Distance from roads

The maximum distance between roads and Land Use Class 4 only grew slightly between 2010 and 2020, from 3.4 km to 4 km. However, this is still likely showing the expansion of this land use between the reference years. The trends observed in the analysis of Land Use Class 4 in relation to distance from settlements are repeated in this analysis. All parameters, including the significant increase in total polygons analysed (Friedman statistic = 5, p value = 0.03), show strong growth in this industry in the 10-year period. Interestingly, where sites of permanent cultivation were not located within close proximity to settlements, the majority of this Land Use Class is actually located in close proximity (less than 1 km) to roads. This indicates the industrial nature of this Land Use Class and the requirement for transport networks. While most of this development is close to roads the measurements also show that there is some notable growth in the distance categories further away from roads. Indeed, there appears to be some large continuous units which are located between 2.5 and 4 km away from roads (Table 9).

Table 9: Overview of land use change between 2010 and 2020 image groups analysed for Land Use Class 4 in relation to distance from roads in the study area.

Year	Distance category	Ranging from (in m)	To (in m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2010	1	0	674	111	12.3	41.7	2.1	9
2010	2	674	1,347	7	6.6	6.6	6.6	1
2010	3	1,347	2,021	52	25.7	44.2	7.3	2
2010	4	2,021	2,694	0	0.0	0.0	0.0	0
2010	5	2,694	3,368	19	6.5	16.0	0.8	3
			Sum or means value	188	10.2	21.7	3.3	15
2020	1	0	793	1485	26.5	108.3	0.8	56
2020	2	793	1,586	443	31.6	173.6	1.1	14
2020	3	1,586	2,379	319	29.0	67.4	3.4	11
2020	4	2,379	3,172	285	31.6	144.7	1.2	9
2020	5	3,172	3,966	843	140.5	746.7	2.7	6
			Sum or means value	3375	51.9	248.1	1.8	96
			Change from prev. Ref. year (in %)	1694.8	407.9	1044.0	-45.3	

7.3. LAND USE CLASS 5 (Plantations)

7.3.1. Distance from settlements

The maximum distance between plantations and settlements remains relatively stable between 2000 and 2010, however reduces from 19.5 km to 14.5 km between 2010 and 2020. Such a trend may be less of a reflection of the plantation Land Use Class and more an indication of the growth of human settlements in the study period in between the last two reference years. Even with this change the largest units of land covered by this class are continually located in the first distance category, which never exceeds 4 km distance from a settlement. There is a clear yet modest growth in the presence of plantations in the study area between each reference year (no significance, Friedman statistic = 2.8, p value = 0.25). This is shown in the total area covered by this Land Use Class growing by 9.9% between 2000 and 2010 and then by 12.8% between 2010 and 2020. Growth is also shown in the significant increase in total polygons analysed for this Land Use Class between each reference year (Friedman statistic = 6.4, p value = 0.04) (Table 10).

7.3.2. Distance from roads

The maximum distance between roads in the study area and plantations remained relatively stable between each reference year. However, there was a general trend of increasing total area covered by plantations, with a 23.9% increase over the 20-year study period (no significance, Friedman statistic = 0.4, p value = 0.82). The maximum size of a single polygon covered by this Land Use Class increased between each reference year, with a 71.7% increase in the mean maximum size of a single polygon between 2000 and 2020 (no significance, Friedman statistic = 0.4, p value = 0.82). Conversely the mean polygon size analysed for this Land Use Class reduced significantly between each reference year and showed a 17.7% reduction over the 20-year study period (Friedman statistic = 6.4, p value = 0.04). The largest single unit of this Land Use Class was continuously located within the first distance category (i.e. less than 2.5 km from a road), indicating the industrialised nature of plantations and the need for easy access and direct transport links (Table 11).

Table 10: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 5 in relation to distance from settlements in the study area

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	3,799	19,711	21.4	1,073.5	0.4	923
2000	2	3,799	7,599	10,556	11.4	1,163.7	0.5	929
2000	3	7,599	11,398	3,676	12.9	207.3	0.7	286
2000	4	11,398	15,197	366	9.9	41.4	0.7	37
2000	5	15,197	18,996	12	2.4	3.3	1.5	5
			Sum or means value	34,320	11.6	497.8	0.8	2,180
2010	1	0	3,895	20,831	14.7	2,185.1	0.7	1,416
2010	2	3,895	7,790	13,092	13.6	1,630.1	0.4	963
2010	3	7,790	11,685	3,493	18.1	400.3	0.7	193
2010	4	11,685	15,580	281	7.0	51.6	0.7	40
2010	5	15,580	19,474	10	1.7	2.9	1.0	6
			Sum or means value	37,707	11.0	854.0	0.7	2,618
			Change from prev. ref. year (%)	9.9	-4.8	71.5	-10.2	
2020	1	0	2,899	20,278	17.1	2,531.7	0.4	1,187
2020	2	2,899	5,798	12,775	10.9	592.7	0.4	1,177
2020	3	5,798	8,697	6,980	14.9	710.5	0.3	470
2020	4	8,697	11,596	2,396	18.4	477.1	0.5	130
2020	5	11,596	14,494	95	3.8	33.9	0.5	25
			Sum or means value	42,524	13.0	869.2	0.4	2,989
			Change from prev. ref year (%)	12.8	17.9	1.8	-39.2	

Table 11: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 5 in relation to distance from roads in the study area

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	2,555	27,351	19.4	1,163.7	0.4	1,407
2000	2	2,555	5,110	5,230	10.3	440.8	0.5	510
2000	3	5,110	7,665	1,400	7.0	142.0	0.7	200
2000	4	7,665	10,220	319	5.9	42.3	0.7	54
2000	5	10,220	12,774	21	2.3	8.4	0.7	9
			Sum or means value	34,321	9.0	359.4	0.6	2,180
2010	1	0	2,551	32,012	15.7	2,185.10	0.6	2,034
2010	2	2,551	5,101	4,661	10.9	252.4	0.4	429
2010	3	5,101	7,652	855	8.5	101.7	0.7	101
2010	4	7,652	10,202	115	4.0	16.6	0.7	29
2010	5	10,202	12,753	64	2.6	11.14	0.7	25
			Sum or means value	37,707	8.3	513.4	0.6	2,618
			Change from prev. ref. year (%)	9.9	-7.3	42.8	3.1	
2020	1	0	2,563	36,587	15.7	2,531.7	0.4	2,330
2020	2	2,563	5,126	4,928	10.2	413.9	0.3	483
2020	3	5,126	7,689	915	6.7	118.1	0.5	136
2020	4	7,689	10,252	62	2.4	14.2	0.5	26
2020	5	10,252	12,815	32	2.2	8.7	0.5	14
			Sum or means value	42,524	7.4	617.3	0.5	2,989
			Change from prev. ref. year (%)	12.8	-10.6	20.3	-27.6	

7.4. LAND USE CLASS 6 (Medium to severe deforestation/degradation and old lands)

7.4.1. Distance from settlements

Across all reference years the largest single units of land covered by Land Use Class 6 are continually located within close proximity to settlements (i.e. no further than 4.2 km away from settlements). Such a trend shows the strong human role in deforestation and degradation. Interestingly the total land covered by this Land Use Class increases by over 40% between 2000 and 2010, but then reduces by 66.5% between 2010 and 2020 (no significance, Friedman statistic = 0.4, p value = 0.82). As little evidence of land restoration was found in the land use change analysis this is most likely indicative of further development/transformation of the land from this intermediate state of deforestation to a more cultivated and anthropogenically transformed landscape such as those found under Land Use Class 3. There was strong growth (of 146%) in the maximum size of a single polygon covered by this Land Use Class within the first distance category in between 2000 and 2010 (no significance, Friedman statistic = 0.2, p value = 0.66). However, this then reduced by 60% between 2010 and 2020. Notably there was a reduction in the size of a single unit of this Land Class from 19,392 ha in 2010 to 8,154 ha in 2020 (no significance, Friedman statistic = 1.8, p value = 0.18) (Table 12).

Table 12: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 6 in relation to distance from settlements in the study area.

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	4,077	73,374	12.2	6,160.6	0.5	6,014
2000	2	4,077	8,154	35,989	8.8	2,252.7	0.6	4,100
2000	3	8,154	12,231	10,783	10.6	977.3	0.7	1,014
2000	4	12,231	16,307	1,422	5.3	140.8	0.5	268
2000	5	16,307	20,384	331	25.5	127.4	0.7	13
			Sum or means value	121,899	12.5	1,931.8	0.6	11,409
2010	1	0	4,223	122,397	21.1	19,392.0	0.6	5,796
2010	2	4,223	8,446	38,898	8.8	3,327.0	0.7	4,436
2010	3	8,446	12,668	7,936	7.6	474.7	0.7	1,044
2010	4	12,668	16,891	1,061	5.2	67.4	0.7	203
2010	5	16,891	21,114	696	22.5	499.3	0.7	31
			Sum or means value	170,989	13.0	4,752.1	0.7	11,510
			Change from prev. ref. year (%)	40.3	4.5	146.0	9.8	
2020	1	0	3,644	29,991	8.5	8,154.3	0.3	3,522
2020	2	3,644	7,288	17,997	5.9	403.5	0.5	3,039
2020	3	7,288	10,932	7,457	7.2	419.1	0.5	1,040
2020	4	10,932	14,576	1,294	7.2	276.1	0.5	180
2020	5	14,576	18,220	488	19.5	231.7	0.3	25
			Sum or means value	57,227	9.7	1,896.9	0.4	7,806
			Change from prev. ref. year (%)	-66.5	-25.9	-60.1	-39.5	

7.4.2. Distance from roads

The maximum distance between a road and Land Use Class 6 varies little between each reference year, with the maximum distance away from roads being 14 km in 2010 and 13.3 km in 2020. While it is likely that this trend is related to the transitory nature of this Land Use Class this reduction in maximum distance could also be related to the development of new road networks in the study area. Indeed, better access to this Land Use Class, as facilitated through road development, may actually speed up the transformation and further degradation of land covered by this Land Use Class. Further transformation of land covered by Land Use Class 6 is evidenced by the overall reduction in both the total polygons analysed (no significance, Friedman statistic = 5.2, p value = 0.08) and the mean size of polygon analysed (no significance, Friedman statistic = 4.8, p value = 0.09). The increase in mean area and total polygons analysed (no significance, Friedman statistic = 5.2, p value = 0.07) between 2000 and 2010 highlights an increase in the presence of medium to severe deforestation in the landscape. Yet the reduction in both parameters between 2010 and 2020 shows landscape transformation away from this Land Use Class, likely towards more heavily cultivated landscapes (Table 13).

Table 13: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 6 in relation to distance from roads in the study area.

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	2,774	96,506	11.4	6,160.6	0.5	8,471
2000	2	2,774	5,548	16,960	8.6	2,252.7	0.7	1,974
2000	3	5,548	8,322	5,578	8.2	886.5	0.7	677
2000	4	8,322	11,096	2,619	11.1	446.8	0.7	236
2000	5	11,096	13,870	235	4.6	55.4	0.7	51
			Sum or means value	121,899	8.8	1,960.4	0.7	11,409
2010	1	0	2,805	142,414	17.1	19,392.0	0.6	8,335
2010	2	2,805	5,610	17,961	8.2	342.1	0.7	2,197
2010	3	5,610	8,415	8,316	11.9	946.8	0.7	699
2010	4	8,415	11,220	1,781	7.7	149.5	0.7	231
2010	5	11,220	14,025	517	10.8	126.4	0.7	48
			Sum or means value	170,988	11.1	4,191.3	0.7	11,510
			Change from prev. ref. year (%)	40.3	26.7	113.8	4.3	
2020	1	0	2,665	40,349	7.6	8,154.1	0.3	5,322
2020	2	2,665	5,330	10,782	6.6	430.3	0.5	1,627
2020	3	5,330	7,996	4,211	7.2	415.5	0.3	600
2020	4	7,996	10,661	1,833	7.9	370.4	0.5	233
2020	5	10,661	13,326	51	2.1	13.2	0.5	24
			Sum or means value	57,227	6.3	1,876.7	0.4	7,806
			Change from prev. ref. year (%)	-66.5	-43.5	-55.2	-39.5	

7.5. LAND USE CLASS 7 (Sparse woodlands and grasslands)

7.5.1. Distance from settlements

The majority of the land covered by Land Use Class 7 is located within 4.5 km of settlements in each reference year. Indeed, the maximum distance between the Land Use Class and a settlement remains the same (22.3 km) across the reference years. There is a steady decline in the total area covered by sparse woodlands and grasslands across each reference year, with a decline of 27% over the 20-year period (no significance, Friedman statistic = 1.6, p value = 0.45). The largest single area covered by Land Use Class 7 grew slightly between 2000 and 2010 to a maximum of 36,424 ha, however it then reduced by over 12,000 ha between 2010 and 2020 to 24,180 ha (no significance, Friedman statistic = 2, p value = 0.37). Such a change is likely due to the growth of human settlements and the inevitable land transformation which occurs within close proximity to settlements. Encouragingly there appears to be little change in the distribution or occurrence of this Land Use Class between 13.4 and 22.3 km away from settlements. This may suggest somewhat of a stronghold of this vegetation type which is important for ecological process (Table 14).

Table 14: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 7 in relation to distance from settlements in the study area.

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	4,450	62,510	52.7	33,156.6	0.7	1,186
2000	2	4,450	8,900	13,440	14.1	6,875.9	0.5	953
2000	3	8,900	13,350	4,803	11.7	781.2	0.7	411
2000	4	13,350	17,800	1,981	14.3	323.9	0.7	139
2000	5	17,800	22,250	998	23.8	545.5	0.7	42
			Sum or means value	83,732	23.3	8,336.6	0.7	2,731
2010	1	0	4,450	47,025	74.4	36,424.0	0.7	632
2010	2	4,450	8,900	12,604	22.0	6,868.6	0.7	573
2010	3	8,900	13,350	4,288	12.8	767.1	0.7	336
2010	4	13,350	17,800	2,253	16.3	322.0	0.6	138
2010	5	17,800	22,250	995	23.7	545.5	0.7	42
			Sum or means value	67,164	29.8	8,985.4	0.7	1,721
			Change from prev. ref. year (%)	-19.8	28.0	7.8	4.3	
2020	1	0	4,450	40,019	82.7	24,180.5	0.5	484
2020	2	4,450	8,900	12,814	28.4	6,874.0	0.5	452
2020	3	8,900	13,350	5,349	17.1	1,113.5	0.5	312
2020	4	13,350	17,800	1,966	15.7	323.7	0.5	125
2020	5	17,800	22,250	1,000	22.7	545.5	0.5	44
			Sum or means value	61,149	33.3	6,607.4	0.5	1,417
			Change from prev. ref. year (%)	-9.0	11.7	-26.5	-27.2	

7.5.2. Distance from roads

In a similar pattern to that observed between the presence of sparse woodlands and grasslands in relation to settlements, the majority of this Land Use Class is found within 3 km of roads in the landscape. This is likely a result of the high road density in the area. There is a significant trend of reduction in the total area of this Land Use Class in the study area suggesting a transformation away from this relatively natural landscape (Friedman statistic = 6.4, p value = 0.04). There is also a significant reduction in the total polygons analysed for this Land Use Class (Friedman statistic = 10, p value = 0.007) The significant increase in mean size of a single unit of this Land Use Class (Friedman statistic = 7.6, p value = 0.02) indicates that there are large swathes of sparse woodlands and grasslands which are relatively untouched, but a transformation of smaller patches (Table 15).

Table 15: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 7 in relation to distance from roads in the study area.

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	2,773	70,361	37.1	33,156.6	0.5	1896
2000	2	2,773	5,546	11,165	20.5	6,875.9	0.7	545
2000	3	5,546	8,318	1,382	6.7	155.7	0.7	205
2000	4	8,318	11,091	775	11.2	323.9	0.7	69
2000	5	11,091	13,864	48	3.0	14.6	0.7	16
			Sum or means area	83,732	15.7	8,105.3	0.7	2731
2010	1	0	2,826	54,397	46.4	36,424.0	0.6	1173
2010	2	2,826	5,651	10,520	30.5	6,868.6	0.7	345
2010	3	5,651	8,477	1,549	11.5	453.9	0.7	135
2010	4	8,477	11,303	653	11.7	322.0	0.7	56
2010	5	11,303	14,129	46	3.8	13.8	0.7	12
			Sum or means area	67,164	20.8	8,816.5	0.7	1721
			Change from prev. ref. year (%)	-19.8	32.1	8.8	4.9	
2020	1	0	2,771	48,881	51.9	24,180.5	0.5	942
2020	2	2,771	5,542	10,543	35.6	6,874.0	0.5	296
2020	3	5,542	8,314	1,068	8.0	117.8	0.5	133
2020	4	8,314	11,085	620	17.7	323.7	0.5	35
2020	5	11,085	13,856	38	3.5	14.6	0.6	11
			Sum or means area	61,149	23.3	6,302.1	0.5	1417
			Change from prev. ref. year (%)	-9.0	12.4	-28.5	-24.1	

7.6. LAND USE CLASS 8 (Open to dense woodlands)

7.6.1. Distance from settlements

The maximum distance between settlements and land classified as open to dense woodlands remains at a consistent 22 km across the reference years. In each reference year the largest total area covered by this Land Use Class is found less than 4.4 km away from settlements. This is likely indicative of the high presence of settlements in the study area. There is a downwards trend in the total area covered by this Land Use Class between each reference year, showing a significant reduction of 45% over the 20-year study period (Friedman statistic = 8.4, p value = 0.02). This reduction is also mirrored in the significant reduction in the total number of polygons analysed in each reference year (Friedman statistic = 6.4, p value = 0.04). This suggests a human driven transformation of this relatively natural landscape type and potential degradation. The reduction in this Land Use Class within close proximity to settlements supports this notion. Interestingly, there appears to be a large unit of open to dense woodlands less than 4.4 km away from settlements in the study area which remains steadfast throughout the study period. This perhaps suggests that there is transformation of smaller units of this Land Use Class but an effort to preserve larger areas (Table 16).

Table 16: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 8 in relation to distance from settlements in the study area.

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	4,388	263,439	43.4	48,176.7	0.2	6,072
2000	2	4,388	8,775	41,391	10.5	2,221.9	0.3	3,962
2000	3	8,775	13,163	9,419	8.3	573.7	0.5	1,137
2000	4	13,163	17,551	4,487	14.9	1,074.2	0.5	302
2000	5	17,551	21,939	868	13.99	258.5	0.7	62
			Sum or means value	319,603	18.2	10,461.0	0.4	11,535
2010	1	0	4,388	153,790	34.6	58,807.8	0.1	4,449
2010	2	4,388	8,775	30,924	9.3	1,526.5	0.2	3,341
2010	3	8,775	13,163	8,429	9.5	644.6	0.7	890
2010	4	13,163	17,551	4,482	15.6	1,082.4	0.7	287
2010	5	17,551	21,939	706	17.6	259.3	0.7	40
			Sum or means value	198,330	17.3	12,464.1	0.5	9,007
			Change from prev. ref. year (%)	-37.9	-4.8	19.1	9.0	
2020	1	0	4,388	137,841	45.2	45,984.5	0.3	3,051
2020	2	4,388	8,775	26,388	9.4	1,829.7	0.3	2,817
2020	3	8,775	13,163	6,962	8.3	464.7	0.5	838
2020	4	13,163	17,551	3,960	17.1	1,057.1	0.5	232
2020	5	17,551	21,939	777	18.1	258.5	0.5	43
			Sum or means value	175,927	19.6	9,918.9	0.4	6,981
			Change from prev. ref. year (%)	-11.3	13.2	-20.4	-13.6	

7.6.2. Distance to roads

The maximum distance between roads in the study area and areas covered by Land Use Class 8 remains relatively stable across the reference years, however the trend of reducing presence of this Land Use Class is repeated here. Overall, there is a near significant loss of open to dense woodlands across the study period (Friedman statistic = 5.2, p value = 0.07), but it appears that the greatest loss is found less than 6 km away from roads in the landscape. This does suggest that increased access to areas covered by Land Use Class 8 places them under greater threat of transformation. This suggestion is further supported through the relative stronghold of this Land Use Class at distances greater than 10 km away from roads in the study area. It appears that inaccessibility is a factor in the preservation of these landscapes (Table 17).

Table 17: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 8 in relation to distance from roads in the study area.

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	2,746	281,758	34.4	48,176.7	0.2	8,197
2000	2	2,746	5,492	23,300	10.6	1,882.3	0.5	2,209
2000	3	5,492	8,238	10,992	14.4	1,207.4	0.5	766
2000	4	8,238	10,984	2,974	10.4	415.6	0.5	285
2000	5	10,984	13,730	580	7.4	251.6	0.5	78
			Sum or means value	319,603	15.4	10,386.7	0.5	11,535
2010	1	0	2,802	173,974	27.0	58,807.8	0.1	6,435
2010	2	2,802	5,605	13,763	8.2	1,082.4	0.5	1,687
2010	3	5,605	8,407	6,875	12.0	1,229.0	0.7	575
2010	4	8,407	11,210	2,619	10.6	307.7	0.7	248
2010	5	11,210	14,012	1,098	17.7	644.6	0.7	62
			Sum or means value	198,330	15.1	12,414.3	0.5	9,007
			Change from prev. ref. year (%)	-37.9	-2.2	19.5	18.9	
2020	1	0	2,746	156,533	33.1	45,984.5	0.3	4,730
2020	2	2,746	5,492	10,922	7.4	1,057.1	0.5	1,482
2020	3	5,492	8,238	5,630	11.0	1,208.5	0.5	510
2020	4	8,238	10,984	1,842	9.0	307.4	0.5	205
2020	5	10,984	13,730	1,000	18.5	464.7	0.6	54
			Sum or means value	175,927	15.8	9,804.4	0.5	6,981
			Change from prev. ref. year (%)	-11.3	4.7	-21.0	-14.0	

7.7. LAND USE CLASS 9 (Degraded closed woodlands and forests)

7.7.1. Distance to settlements

The maximum distance between settlements and Land Use Class 9 remains relatively stable across the reference years. There is a significant increase in the presence of this Land Use Class across the reference years, particularly less than 8.5 km away from settlements (Friedman statistic = 7.6, p value = 0.02). This suggests transformation of closed woodlands and forests (Land Use Class 10) from natural states to degraded states. This is further supported through the reduction in total polygons analysed for this Land Use Class (no significance, Friedman statistic = 0.4, p value = 0.82), which, when assessed with the increasing total area covered by degraded closed woodlands and forests, indicates an amalgamation of this type of land and perhaps a degradation of small patches of natural forest in between larger areas of already degraded woodlands and forests (Table 18).

Table 18: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 9 in relation to distance from settlements in the study area.

Year	Distance category	Ranging from (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	4,230	10,255	8.7	1,419.7	0.2	1,175
2000	2	4,230	8,461	22,016	15.8	5,652.1	0.2	1,391
2000	3	8,461	12,691	4,542	7.4	175.8	0.4	613
2000	4	12,691	16,921	2,255	8.0	247.9	0.7	281
2000	5	16,921	21,152	317	5.9	114.2	0.7	54
		Sum or means value		39,386	9.2	1,521.9	0.5	3,514
2010	1	0	4,248	20,145	18.8	2,645.0	0.0	1,070
2010	2	4,248	8,496	27,262	22.0	9,546.5	0.0	1,237
2010	3	8,496	12,744	5,739	10.3	331.8	0.1	557
2010	4	12,744	16,992	2,653	9.2	305.6	0.6	287
2010	5	16,992	21,240	556	7.7	124.4	0.8	72
		Sum or means value		56,356	13.6	2,590.6	0.3	3,223
		Change from prev. ref. year (%)		43.1	48.6	70.2	-33.9	
2020	1	0	4,230	29,504	40.6	4,958.7	0.3	726
2020	2	4,230	8,461	30,341	30.6	12,362.3	0.2	990
2020	3	8,461	12,691	4,954	8.4	326.0	0.3	593
2020	4	12,691	16,921	2,615	8.9	417.5	0.5	293
2020	5	16,921	21,152	850	9.2	131.4	0.5	92
		Sum or means value		68,265	19.6	3,639.2	0.4	2,694
		Change from prev. ref. year (%)		21.1	43.5	40.5	17.1	

7.7.2. Distance to roads

There is strong growth in the total area covered by degraded closed woodlands and forests between each reference year with particular emphasis on the areas located less than 3 km away from roads (no significance, Friedman statistic = 1.6, p value = 0.45). This suggests that land which is easily accessed is likely to be degraded and transformed from its most natural state. The 114% growth in this Land Use Class less than 3 km from roads in the landscape supports this notion. Furthermore, the increasing maximum size of a single unit of land covered by degraded closed woodlands and forests suggests that where land was previously undegraded, human driven transformation is occurring to merge units to create fully degraded areas (no significance, Friedman statistic = 2.8, p = 0.25) (Table 19).

Table 19: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 9 in relation to distance from roads in the study area.

Year	Distance category	Ranging From (m)	To (m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	2,685	26,717	13.0	5,652.1	0.2	2,058
2000	2	2,685	5,369	8,541	10.0	885.4	0.3	856
2000	3	5,369	8,054	2,920	7.4	150.6	0.4	393
2000	4	8,054	10,738	1,079	6.4	124.6	0.2	168
2000	5	10,738	13,423	131	3.3	20.2	0.2	39
			Sum or means value	39,387	8.0	1,366.6	0.3	3,514
2010	1	0	2,716	43,663	22.3	9,546.5	0.1	1,961
2010	2	2,716	5,431	8,148	10.7	470.6	0.0	765
2010	3	5,431	8,147	3,303	10.9	278.1	0.1	304
2010	4	8,147	10,862	1,056	6.6	103.8	0.3	161
2010	5	10,862	13,578	186	5.8	54.4	0.8	32
			Sum or means value	56,356	11.2	2,090.7	0.2	3,223
			Change from prev. ref. year (%)	43.1	39.8	53.0	-10.2	
2020	1	0	2,716	57,084	37.4	12,362.3	0.2	1,525
2020	2	2,716	5,431	6,647	10.0	570.8	0.3	666
2020	3	5,431	8,147	3,105	10.5	321.7	0.4	297
2020	4	8,147	10,862	1,231	7.4	326.0	0.3	166
2020	5	10,862	13,578	197	4.9	53.2	0.2	40
			Sum or means value	68,265	14.0	2,726.8	0.3	2,694
			Change from prev. ref. year (%)	21.1	25.0	30.4	13.8	

7.8. LAND USE CLASS 10 (Closed woodlands and forests)

7.8.1. Distance to settlements

The maximum distance between settlements and closed woodlands and forests remains stable across the reference years. However, there is a clear reduction in the presence of this Land Use Class in the study area between 2000 and 2020. The greatest reduction is found less than 4.4 km away from settlements indicating the role of human activity in the loss of this natural landscape. Evidence of attrition of a large unit of closed woodlands and forests within close proximity to settlements in the study area is shown by a 24.1% reduction in the size of the largest single area covered by this Land Use Class between 2000 and 2020 (no significance, Friedman statistic = 2.5, p value = 0.28). Yet interestingly there is also evidence of recovery of this Land Use Class between 2010 and 2020 at a distance of between 4.4 and 8.7 km away from settlements. This does suggest protection of landscapes and conservation action to preserve natural landscapes (Table 20).

Table 20: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 10 in relation to distance from settlements in the study area.

Year	Distance category	Ranging from (in m)	To (in m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0.0	4,383	297,460	88.5	84,081.2	0.4	3,363
2000	2	4,383	8,766	48,472	21.5	12,785.4	0.4	2,253
2000	3	8,766	13,150	6,215	9.2	697.9	0.5	672
2000	4	13,150	17,533	1,673	7.8	228.4	0.7	214
2000	5	17,533	21,916	381	6.9	42.1	0.8	55
			Sum or means value	354,201	26.8	19,567.0	0.6	6,557
2010	1	0.0	4,383	257,300	101.3	69,319.9	0.2	2,541
2010	2	4,383	8,766	36,632	18.9	6,491.6	0.5	1,943
2010	3	8,766	13,150	6,936	10.3	698.0	0.4	672
2010	4	13,150	17,533	1,814	7.9	227.7	0.5	230
2010	5	17,533	21,916	378	6.9	42.1	0.8	55
			Sum or means value	303,061	29.0	15,355.9	0.5	5,441
			Change from prev. ref. year (%)	-14.4	8.4	-21.5	-14.2	
2020	1	0.0	4,383	225,676	82.1	63,825.4	0.3	2,749
2020	2	4,383	8,766	50,351	22.5	11,954.0	0.4	2,240
2020	3	8,766	13,150	7,282	10.1	696.7	0.5	724
2020	4	13,150	17,533	1,929	7.3	228.4	0.5	265
2020	5	17,533	21,916	358	6.8	42.1	0.4	53
			Sum or means value	285,597	25.7	15,349.3	0.4	6,031
			Change from prev. ref. year (%)	-5.8	-11.4	0.0	-15.7	

7.8.2. Distance to roads

The maximum distance between roads and closed woodlands and forests in the landscape remains steady at less than 14 km. Within 2.7 km of roads in the landscape there is a 20% reduction in the total area covered by this Land Use Class in the 20-year study period (no significance, Friedman statistic = 3.6, p = 0.17). Similar, if less drastic, reductions are noted in all other distance categories. There is a large reduction in the maximum size of a single unit of land covered by closed woodlands and forests between 5.6 km and 8.3 km away from roads in the landscape. This unit reduces from 525.0 ha to 22.6 ha between 2010 and 2020, the cause of which is unclear, however this could be related to industrial developments or the commercial transformation of this particular unit of land for alternative purposes such as greenhouse development (Land Use Class 4) or plantation establishment (Land Use Class 5) (Table 21).

Table 21: Overview of land use change between 2000 and 2020 image groups analysed for Land Use Class 10 in relation to distance from roads in the study area.

Year	Distance category	Ranging from (in m)	To (in m)	Sum of area (ha)	Mean area (ha)	Max area (ha)	Min area (ha)	Count of polygons analysed
2000	1	0	2,774	325,764	70.7	84,081.2	0.4	4,607
2000	2	2,774	5,548	22,615	16.7	7,917.7	0.7	1,357
2000	3	5,548	8,322	4,764	10.9	522.2	0.7	436
2000	4	8,322	11,096	992	7.1	74.3	0.7	140
2000	5	11,096	13,870	65	3.8	14.6	0.7	17
			Sum or means value	354,200	21.8	18,522.0	0.6	6,557
2010	1	0	2,774	279,698	75.1	69,319.9	0.2	3,723
2010	2	2,774	5,548	18,351	15.0	6,294.2	0.5	1,223
2010	3	5,548	8,322	3,927	11.4	525.0	0.7	344
2010	4	8,322	11,096	1,027	7.5	58.1	0.7	137
2010	5	11,096	13,870	59	4.2	14.6	0.7	14
			Sum or means value	303,061	22.6	15,242.4	0.6	5,441
			Change from prev. ref. year (%)	-14.4	3.7	-17.7	-11.5	
2020	1	0	2,774	260,271	64.4	63,825.4	0.3	4,041
2020	2	2,774	5,548	19,589	14.3	6,296.5	0.4	1,372
2020	3	5,548	8,322	4,419	10.1	22.6	0.5	437
2020	4	8,322	11,096	1,257	7.6	79.8	0.5	166
2020	5	11,096	13,870	60	4.0	14.6	0.3	15
			Sum or means value	285,597	20.1	14,047.8	0.4	6,031
			Change from prev. ref year (%)	-5.8	-11.3	-7.8	-35.8	

8. DISCUSSION

The land use change analysis between 2000 and 2020 presented in this report provides a broad reference baseline in terms of the land use and land use change / transformation in the study area. It highlights a number of key issues for consideration by the owners of the project. The main apparent change is one of a landscape in flux from a semi agricultural one in 2000 to one where agriculture is dominant and interspersed with pockets of more natural ground that are typically under retreat and progressively confined to sections of land under some form of conservation status. The land use change trend in the study area highlights agricultural activities (land use classes 3 – 6) "eating" away 1.23% of the land per annum between 2000 and 2010, and a retreat of natural land (land use classes 7,8 & 10) at near equivalent rhythm of -1.37% per annum in the study area between 2000 and 2010. The trend slows down between 2010 and 2020 with the agricultural activities expanding in area by 0.18% per annum during that period while natural land retreats by -0.33% per annum. If annualised over the 20 years period, this represents agricultural expansion at a rhythm of 0.71% per annum between 2000 and 2020 while natural land decreased at a rate of -0.85% per annum over the same period. In parallel to this agricultural expansion and natural land retreat there is a clear degradation of land under woodland or forest cover, most likely associated to the agricultural expansion but also the need for wood resources by local people in expanding cities and rural communities. Woodland and forest land degradation expanded at a rate of 0.12% per annum between 2000 and 2010 while it slowed down to 0.09% per annum between 2010 and 2020. The annualised rate of change over the 2000 to 2020 period is 0.10% per annum. The annual rate of change in natural lands highlighted above is substantially over the figures for primary forest deforestation for Kenya (Mongabay, 2020) which are -0.40% per annum between 2000 and 2010 and -0.26% per annum between 2010 and 2020. When forest land (any land where 30% cover is represented by tree) is considered, under a wider definition, the situation in the study area is extreme during 2000 and 2010 as in Kenya in general, land under forest cover actually increased by 0.05% per annum during that period. While a decrease in land under forest cover is evident in Kenya between 2010 and 2020, the annualised rate was -0.48%, which is half the rate observed in the study area. Based on Global Forest Watch (2020), Nakuru county was the county with the second highest level of deforestation between 2001 and 2020, with shifting agriculture being the main culprit (responsible for 93.6% of the changes noted in the Global Forest Watch summary of 2020). It is believed that this is reflected here through the very high rate of loss of natural land, and the fact that conversion to agriculture represents +/- 90% of the surface area lost by natural lands. This situation sets the context for the Nairobi-Nakuru-Mau Summit Highway Project, and highlights the particularly essential nature of keeping isolated fragments of natural habitat connected across the landscape.

Agriculture is an essential sector to Kenya. It contributes 26% of the nation's GDP and adds another 27% through links with other sectors (FAO, 2021). This is clear in this land use and land use change analysis. Even at the start of the study period, in 2000, agricultural activities were present and there was clear evidence of landscape transformation away from natural states. While there is evidence of both subsistence and commercial agriculture, it is the development of permanent cultivation which is one of the largest changes recorded over the study period. Industrialised agriculture, in the form of permanent cultivation or greenhouse development, grew rapidly in the landscape between 2010 and 2020. This aligns with a period of rapid economic growth in Kenya which commenced around 2015. During this time the growth rate was around 5.7% and investor confidence was high (World Bank, 2021). Such conditions would have likely supported the development of large-scale agriculture and the establishment of mining and mineral extraction, a Land Use Class which also observed significant growth in the study area between 2010 and 2020.

Agriculture has remained steadfast in the Kenyan economy despite many threats including the emergence of COVID-19 and the subsequent restrictions on movement which occurred in 2020. In this year, where many of Kenya's key industries including tourism began to suffer, agriculture continued to thrive (World Bank, 2021). This economic stronghold has been extremely important for nationwide prosperity as around 40% of Kenya's citizens are employed in the agricultural sector. This figure rises to 70% when looking specifically at the nation's rural population (FAO, 2021). It is these opportunities for employment which are a key driver of the development and expansion of towns and cities in the study area. This link is easy to comprehend considering that many Kenyan citizens still suffer from high rates of food insecurity and around 40% of the population is believed to live on less than 2 USD per day.

Currently Kenya's population sits at 47.6 million. However, it is projected to grow to 81 million by 2039 (FAO, 2021). Kenya's youth (those aged below 15 years old) currently comprise 39% of the population (Government of Kenya, 2020). This growing population will be in need of sustainable employment and it is reasonable to consider that agriculture will continue to play a key role in providing employment opportunities. However, with this in mind it is also important to consider the effects of these social and economic developments on Kenya's levels of biodiversity.

Unfortunately, only 20% of Kenya's land is suitable for agricultural development. In cases of small scale and subsistence agriculture it is likely that this is only discovered post land degradation thus there is great potential for futile forest loss in the study area (USAID, 2021). This is a particular risk going forward as the population expands and transforms more land towards cultivation. In addition to this, Kenya is extremely vulnerable to the effects of climate change and has already started to experience droughts and desertification (FAO, 2021). Preserving forests and natural landscapes in the study area is extremely important for protecting ecosystem services and preserving the ecological integrity of the region in order to increase its resilience to climate change and extreme events. Natural landscapes are of limited distribution in the study area, in 2020 they covered just over 20% of the entire study area. With clear industrial growth it is not unreasonable to consider that more of these landscapes may be lost in the future.

Acknowledging the threats facing the nation's forests, Kenya has received a 'Reducing Emissions through Deforestation and Land Degradation' (REDD+) grant of USD 3.88 million. This allowed multiple governmental and community-based organisations, including the Ministry of Environment and Forestry, the Kenya Forest Service and the National Land Commission to work together to establish both baseline levels of forests and emissions and to develop community-based forest management models (Forest Carbon Partnership Facility, 2020). Such models will become increasingly important as they offer a means of creating sustainable conservation solutions in the face of growing pressure on landscapes.

Kenya is a nation which is highly dependent on nature-based tourism. Preserving its biodiversity is thus not only integral to the nation's environmental security, but also for its future economic stability. There is clear evidence of land transformation for agricultural purposes and extractive industries in the study area and little evidence of forest recovery and regeneration. This is likely due to the degraded baseline of biodiversity and the lack of continuous forest in the region. The International Finance Corporation (IFC)'s Performance Standard 6 (2019) requires a definition of natural habitat in a landscape based upon credible scientific analysis including the comparison between current and historical conditions. The IFC states that "*if, in the judgement of a competent professional, the habitat still largely contains the principal characteristics and functions of a native ecosystem(s), it should be considered a natural habitat regardless of some degree of degradation and/or the presence of some invasive alien species, secondary forest, human habitation, or other human-induced alteration*". It also states that natural habitat should be considered as "*areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition*". There is thus still potential for substantial portions of the landscapes of the study area to be considered 'natural'. There is, without doubt, significant transformation and degradation of the landscape, however there are still areas of closed woodlands and forests which offer some potential for the preservation of ecological function. It is therefore important going forward that Kenya balances its need for employment and economic prosperity with environmental integrity maintenance.

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APPENDIX

6-14 *BIODIVERSITY BASELINE INVESTIGATION – VEGETATION, PLANTS AND HABITATS*

Nairobi-Nakuru-Mau Summit Highway Project Expansion & Upgrade Biodiversity baseline studies for the ESIA Republic of Kenya

BIODIVERSITY BASELINE INVESTIGATION VEGETATION, PLANTS AND HABITATS
FINAL REPORT

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BIODIVERSITY BASELINE INVESTIGATION
VEGETATION, PLANTS AND HABITATS

1. CONTEXT

WSP Canada has been commissioned by Rift Valley Highway Limited (RVHL) to complete the Environmental and Social Impact Assessment (ESIA) for the Rironi to Mau Summit Highway Expansion and Upgrade Project. The ESIA is undertaken in order to anticipate and identify adverse environmental and social risks and develop robust mitigation measures through the application of mitigation hierarchy. As part of the WSP Canada consortium in the proposal made to RVHL, Flora Fauna & Man Ecological Services Ltd (FFMES) has been tasked to undertake the biodiversity surveys along the proposed road alignment. A first round of work, covering the dry season was undertaken in February 2021, from 17 to 26 February (10 days of field work). Another round of work, covering the wet season, was undertaken from 13 to 25 April 2021 (12 days of field work). The work was undertaken by a multidisciplinary team of experts spanning the following disciplines

- Vegetation, including woody biomass;
- Mammals (including small terrestrial mammals);
- Avifauna;
- Herpetofauna (Reptiles & Amphibians);
- Freshwater ecology.

The present document provides an outline of the work undertaken with respect to the following discipline:

- Vegetation;
  - Section 1 of 2: Report on the plant diversity and general ecology

- Team leader:	Ben Orban
o Degrees	MSc Wildlife Management
o Professional accreditation	SACNASP Professional Scientist in Ecological & Botanical Science
o Number of years of experience	27
o Number of publications in the field if relevant	16
o Prior experience in the country or region:	East Africa (Ethiopia, Uganda, Tanzania)
- Assistant 1:	Graeme Wolfaard
o Degrees:	M.Sc. Veterinary Sciences, B.Sc. (hons) Wildlife Management
o Professional accreditation:	SACNASP Professional Natural Scientist in Ecological Science
o Number of years of experience:	7
o Prior experience in the country or region:	NA
- Assistant 2:	Itambo Malombe
o Degrees:	PhD Botany
o Prior experience in the country or region	Kenya

2. INTRODUCTION

A major trade route exists from the port in Mombasa, Kenya, to Kampala in the neighbouring Uganda, which is land-locked. The existing single lane road from Nairobi to Nakuru, forming an integral part of the trade route through the Kiambo and Nakuru Districts, do not comply with the requirements of increased demand, being congested (especially many large trucks) with many fatal accidents. It is proposed that the current Nairobi-Nakuru-Mau roadway be increased in width to achieve the higher functionality of a dual highway with improved safety and user control measures implemented in the design. In an attempt to limit further undesirable environmental impact, it is also proposed that the current road delineation be used if possible. The main road is to be called the A8 Highway while the existing Kamandura-Mai Mahiu-Narok Road is to be called the A8 South Highway.

3. STUDY AREA

3.1. Location and general description

The Local Assessment Area extends northwest from Nairobi towards the town of Molo in the Mau Summit region (Figure 1). The Local Assessment Area refers to the existing Road Reserve and Project footprint, or direct influence area associated with implementation of the Project. The Local Assessment Area includes a 2 km buffer, while the Regional Assessment Area includes a 15 km buffer and protected areas.

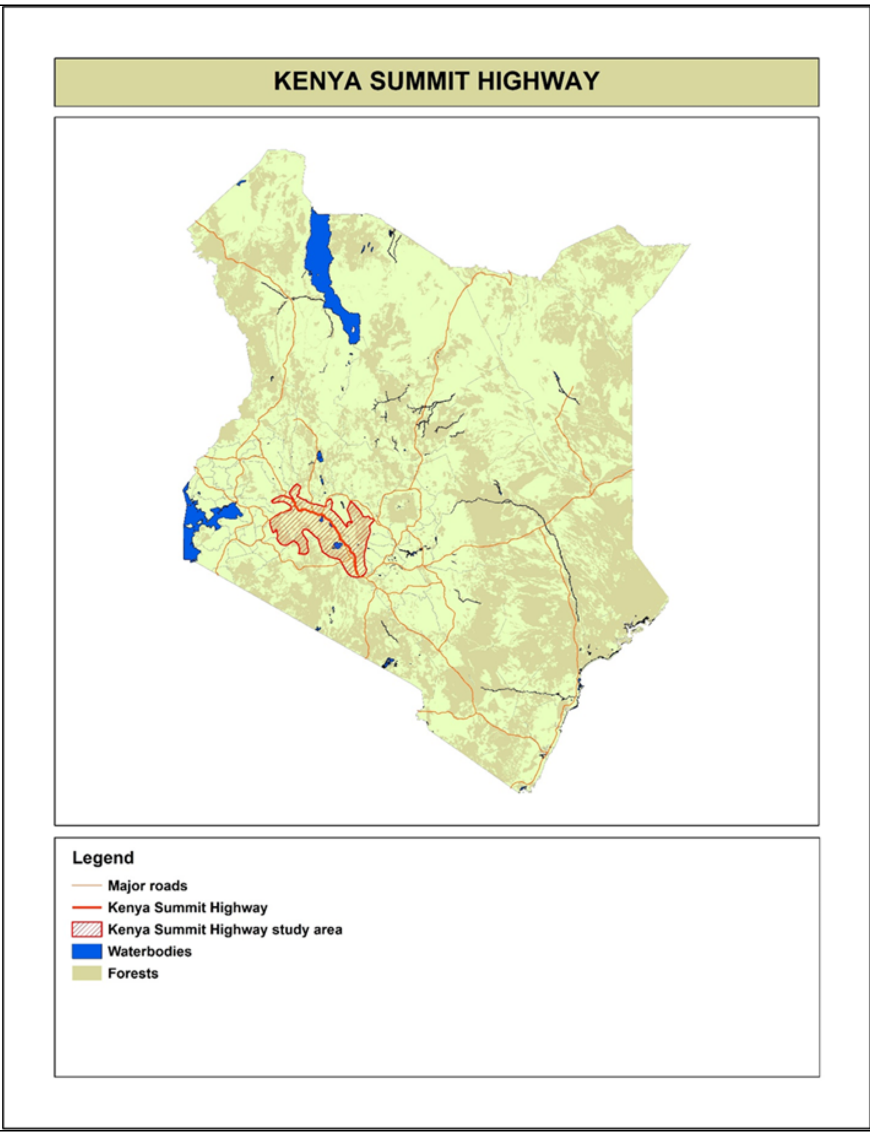


Figure 1: Location and extent of the Regional Assessment Area from Nairobi to Mau Summit, Kenya.

3.2. Topography

From Nairobi, a short section of highway is currently under construction, merging back to single lane traffic all the way to the border post with Uganda. The road climbs from Nairobi at 1,882 m above sea level (asl) to 2,716 m asl (Aberdare Mountain range) over a distance of approximately 45 km, followed by a steep decent to 1,900 m asl (Figure 2). This lower section is characterised by undulating terrain with the existing road passing close to three lakes i.e., Lake Naivasha, Lake Elmenteita and Lake Nakuru (Lake Nakuru National Park). The road climbs again to an altitude of 2,583 m asl at the 187 km mark, reaching the end of this proposed construction phase.

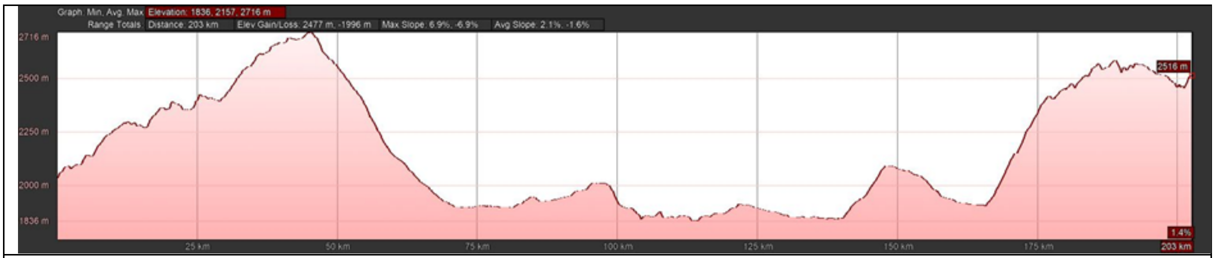


Figure 2: Topography and altitude variation of the proposed road section (Nairobi to Nakuru) to be upgraded.

3.3. Geology

Geology of the Nakuru district is dominated by igneous volcanic rock, notably on the floor of the Rift Valley and on peneplains west and east of the valley. The oldest are of the Lower Miocene age and comprise of eroded lavas and pyroclastic piles, with persistent faulting giving rise to the rift valley and the volcanic piles of Mount Kenya, Elgon and Kilimanjaro. Relatively small intrusions of unconsolidated sedimentary deposits of the Tertiary and Quarternary age are found in tectonic troughs with internal drainage in which fluviatile sediments accumulated. These are typically found as areas surrounding Lake Naivasha, Lake Elmenteita and Lake Nakuru. It is also noteworthy that Nairobi, Nakuru and Lake Naivasha are considered strategic aquifers for which there are no alternative resources. Groundwater extraction has considerable potential in supplementing surface-use water supplies, albeit of poor water quality (fluoride concentrations in the Nairobi aquifer exceeds WHO standards).

3.4. Soil

The geological formations together with the climatic conditions present are ultimately responsible for the unique formation of soils through a process of pedogenesis. The major soil types in Kenya are solonetz, luvisols and cambisols (African Groundwater Atlas 2019)[1]. Solonetzic soils or gumbo soils are characterised by a tough impermeable hardpan of 5 to 30 cm below the surface, severely restricting root penetration and water percolation of the subsoil. Furthermore, this sub-surface soil horizon has higher levels of sodium (Na) and often an accumulation of clay, making crop production a challenge. Luvisols are characterised by clay elluviation from the upper part of the soil profile (usually greyish in colour) to be deposited (illuviation) to an argic B-horizon (commonly brown in colour), often associated with flat or gently sloping land with distinct wet and dry seasons. Luvisols also have favourable properties for agricultural, being well aerated with relatively high water storage capacity in the argic sub-layer. Luvisols are most often associated with cambisols, showing poor pedogenesis and only beginning of horizon differentiation. Cambisols make good agricultural land and most often used for food production, however, cambisols on steep slopes are best kept under forest.

3.5. Climate

Climate change in Kenya has recently led to more frequent extreme weather events like droughts, which last longer than usual, irregular rainfall, flooding and increasing temperatures, increasingly impacting the lives of Kenyans and the environment. Although data are available for Njoro, Menegai, Watalii, Kongoni and Naivasha, the latter is considered more representative of the Nakuru district as a whole. Precipitation can, however, vary from 656 mm

[1] African Groundwater Atlas. 2019. Soil. British Geological Survey. Accessed December 2020. http://earthwise.bgs.ac.uk/

recorded at Watalii to 959 mm per annum recorded at Menegai. Naivasha is located at 1898 m asl and is dominated by warm-summer Mediterranean climate, being warm and temperate with more rainfall in winter than in summer. Temperature and rainfall averages 17.1 °C and 677 mm, respectively.

3.5.1. Rainfall

The Naivasha/Nakuru rift valley area is classified as Csb according to the Koppen-Geiger climate classification i.e., coldest month averaging above 0 °C, all months with average temperatures below 22 °C, and at least four months averaging above 10 °C. Also at least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm. Although a bimodal rainfall pattern can be observed, higher precipitation occurs during the April to May peak, with a second lower peak rainfall recorded in November. The recorded mean annual rainfall at Naivasha is 677 mm, with the driest month in January receiving a mean of 34 mm. The mean highest rainfall of 119 mm is recorded in April. The second peak has a mean rainfall recorded of 68 mm during November (Figure 3).

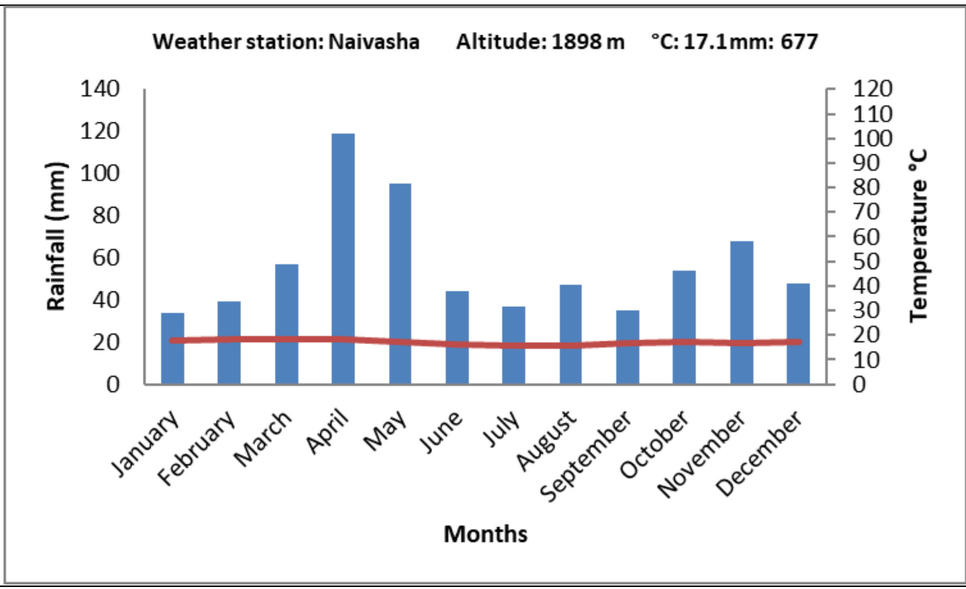


Figure 3: Climatic diagram for Naivasha, Nakuru district, Kenya.

3.5.2. Temperature

The annual amplitude in mean monthly temperature is less than 3°C, from a minimum of 8.4°C in January to a maximum of 27.6°C in February (Table 1). Hence, there is little distinction between hot and cold periods. Temperatures are also correlated with altitude and thus mean monthly temperatures along the Aberdare Mountain range are in all probability appreciably lower than at Nakuru.

Table 1: Monthly rainfall and temperatures for Naivasha, Nakuru district, Kenya

		Temperature					
Month	**Rainfall (mm)**	**°C**	**°C (min)**	**°C (max)**	**°F**	**°F (min)**	**°F (max)**
January	34	17.7	8.4	27.1	63.9	47.1	80.8
February	39	18.2	8.8	27.6	64.8	47.8	81.7
March	57	18.4	10.0	26.9	65.1	50.0	80.4
April	119	18.1	11.3	25.0	64.6	52.3	77.0
May	95	17.3	11.0	23.7	63.1	51.8	74.7
June	44	16.3	9.6	23.0	61.3	49.3	73.4
July	37	15.7	9.1	22.4	60.3	48.4	72.3
August	47	15.9	9.1	22.8	60.6	48.4	73.0
September	35	16.5	8.6	24.5	61.7	47.5	76.1
October	54	17.3	9.2	25.4	63.1	48.6	77.7
November	68	16.9	9.5	24.4	62.4	49.1	75.9
December	48	17.1	8.9	25.4	62.8	48.0	77.7

3.6. Broad-scale habitat description

A large extent of the Local Assessment Area is comprised of areas of cultivation and severe deforestation/degradation (with old lands and minor settlements included), which link villages and towns (Figure 4). These areas are often utilized as road verge grazing for domestic livestock such as cattle, sheep, donkeys and goats as well as subsistence cultivation, particularly between community settlements. These areas are further interspersed with exotic forestry plantations particularly at higher-altitude areas (i.e., the south-eastern extent near Nairobi and the north-western extent near Molo), with the common forestry species being *Cupressus lusitanica*, *Eucalyptus spp.* and *Pinus spp.*

The areas of lower degradation/utilization contain remnants of indigenous vegetation, which provide corridors to facilitate the flow of important ecological patterns and processes that support greater biodiversity. There are nine VECEA habitat types that the Nairobi-Nakuru-Mau Summit Highway Project Regional Assessment Area traverses (Figure 5). In Appendix I, Figure A shows the VECEA habitat types at a finer scale throughout sections of the Local Assessment Area. Photos of each of the VECEA habitat types encountered can be found in Appendix I, Figure B.

Table 2 shows the total area (km^2) that each VECEA habitat type encompasses; and the percentage of this area explicitly designated for biodiversity, species or landscape protection (A) and areas designated for both protection (nationally protected) and sustainable use objectives (B) (Kindt *et al.* 2015, van Breugel *et al.* 2015a, van Breugel *et al.* 2015b). Additional areas occurring within transition zones between vegetation types were not included, however these can be found at http://vecea.vegetationmap4africa.org.

***Note: all species in bold in the brief description of VECEA habitat types below were recorded during one/more of the surveys.**

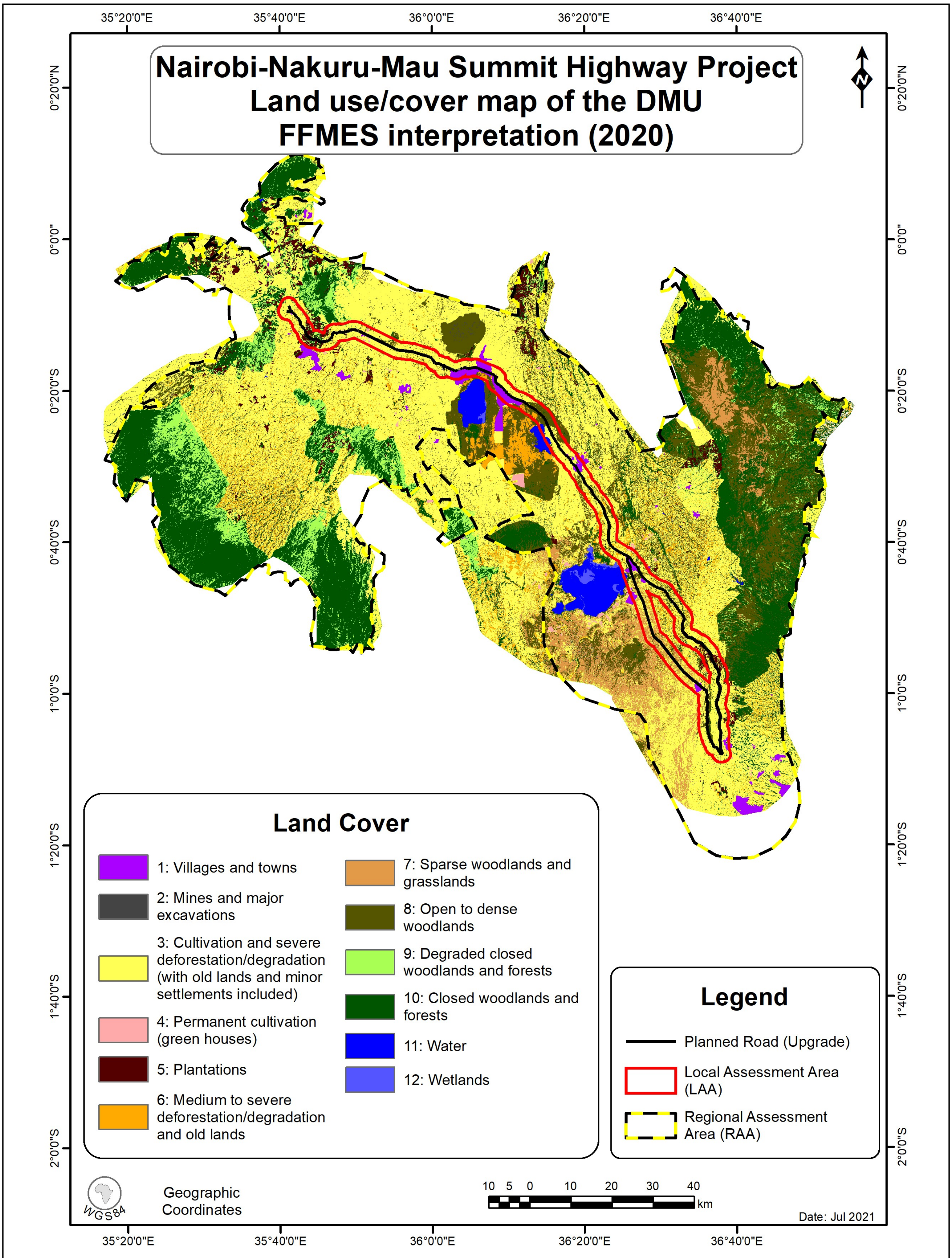


Figure 4: Land use/cover map and habitat types of the proposed Nairobi-Nakuru-Mau Summit Highway Project Regional Assessment Area.

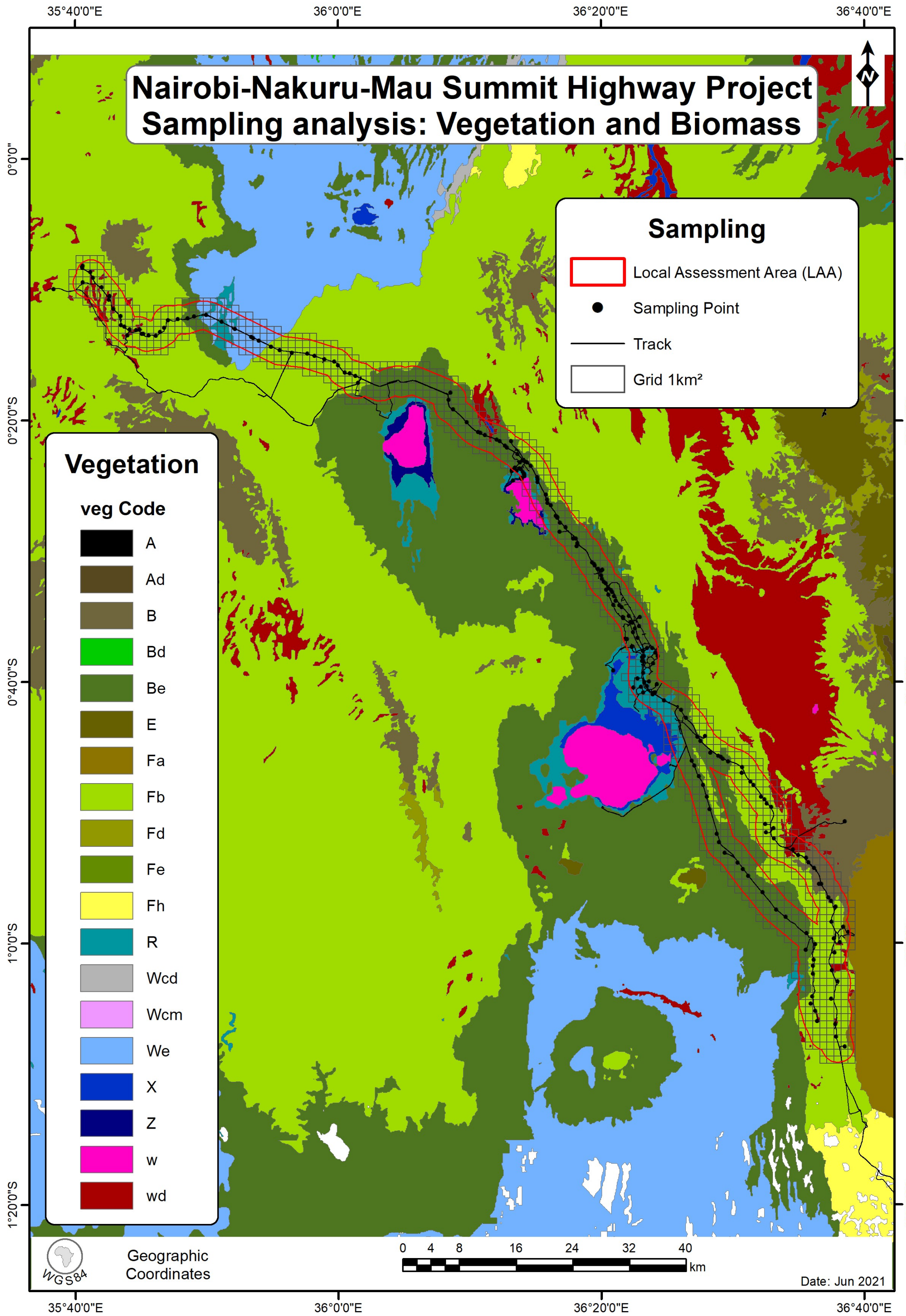


Figure 5: VECEA habitat types that occur throughout the proposed Nairobi-Nakuru-Mau Summit Highway Project Local Assessment Area.

Table 2: VECEA habitat types occurring throughout the Nairobi-Nakuru-Mau Summit Highway Project Regional Assessment Area and the total area (km^2) that each vegetation type encompasses, as well as the percentage of this area explicitly designated for biodiversity, species or landscape protection (A) and areas designated for both protection (nationally protected) and sustainable use objectives (B) (Kindt *et al.* 2015, van Breugel *et al.* 2015a, van Breugel *et al.* 2015b).

Habitat type	Area (km^2)	A (%)	B (%)
Afromontane bamboo (B)	4,084	13.50	66.10
Afromontane rain forest (Fa)	74,291	4.30	32.40
Afromontane undifferentiated forest (Fb)	33,883	4.60	28.50
Edaphic grassland on drainage-impeded or seasonally flooded soils (g)*	48,865	10.60	6.70
Evergreen and semi-evergreen bushland and thicket (Be)	71,708	8.90	7.30
Halophytic vegetation (Z)	6,087	16.70	9.10
Riverine wooded vegetation (R)	7,955	10.00	12.40
Upland Acacia wooded grassland (We)	19,259	15.60	5.20
Freshwater swamp (X) [Water bodies (w)]	29,189	20.80	7.50

*Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd) is a subtype of Edaphic grassland on drainage-impeded or seasonally flooded soils (g)

3.6.1. Afromontane bamboo (B)

This vegetation type encompasses a total area of 4,084 km^2, 13.50% of which is explicitly designated for biodiversity, species or landscape protection and 66.10% of which is designated for both protection and sustainable use objectives (Table 2).

The dominant species of the Afromontane bamboo habitat type is ***Sinarundinaria alpina*** (synonyms: *Arundinaria alpina* and *Yushania alpina*), which is a species of bamboo that occurs on most high mountains throughout East Africa (Kindt *et al.* 2015, van Breugel *et al.* 2015a, van Breugel *et al.* 2015b). It is mostly found between 2400 and 3000 m asl in East Africa, although it ascends on Mt. Kenya to 3500 m asl and descends to 1630 m asl in the Uluguru mountains in Tanzania. It often forms dense, impenetrable patches on deep volcanic soils and gentle slopes in areas that receive an annual rainfall exceeding 1250 mm. As cited in Kindt *et al.* (2015), van Breugel *et al.* (2015a) and van Breugel *et al.* (2015b); White (1983) described the largest areas to exist in Kenya on the Aberdare Range (65 000 ha), the Mau Range (51 000 ha) and Mt. Kenya (39 000 ha).

Expected characteristic plant species are *Cornus volkensii*, *Dombeya torrida*, *Faurea saligna*, ***Hagenia abyssinica***, *Ilex mitis*, ***Juniperus procera***, ***Lepidotrichilia volkensii***, ***Nuxia congesta***, ***Podocarpus latifolius***, ***Prunus africana***, ***Rapanea melanophloeos*** and *Tabernaemontana stapfiana*. Generalist and marginal species expected to be present include ***Hypericum revolutum***, *Schefflera volkensii*, *Agauria salicifolia*, *Peddiea fischeri*, ***Rhamnus prinoides***, *Rubus apetalus* and *Sambucus ebulus*.

3.6.2. Afromontane rain forest (Fa)

This vegetation type encompasses a total area of 74,291 km^2, 4.30% of which is explicitly designated for biodiversity, species or landscape protection and 32.40% of which is designated for both protection and sustainable use objectives (Table 2).

On most mountains the lowermost vegetation is forest, with a transitional zone connecting the forest to the lowland vegetation zone. However, almost everywhere in Kenya this transitional zone has been destroyed by fire and cultivation, with forest being dominant on the lower slopes. Nearly everywhere the vegetation on mountains diminishes in stature from the lower slopes to the summit, dominated by secondary, fire-maintained grasslands (White 1983). Afromontane rain forest is remarkably similar in structure and physiognomy to Guineo-Congolian lowland rain forest with an upper stratum of 25 to 45 tall trees that are heavy branched and wide-spreading; a middle tree stratum of 14 to 30 m tall, with narrow crowns but do not form a dense canopy; a lower tree stratum of

6 to 15 m tall and forming a dense canopy, followed by a shrub layer of 3 to 6 m tall but poorly differentiated from the lower tree layer. The Afromontane rain forest differs from the Guineo-Congolian rain forest in the occurrence of tree ferns ***Cyathea*** *spp*. and ***Podocarpus/Afrocarpus*** *spp*. These forests mainly occur from 1200 – 2500 m asl in areas where the mean annual rainfall lies between 1250 – 2500 mm. Afromontane rainforest is less deciduous than lowland semi-evergreen forests that receive similar rainfall, which is likely due to mist frequently occurring during the dry season.

Characteristic plant species expected are *Chrysophyllum gorungosanum, Cola greenwayi, Cyathea dregei, Cyathea humilis,* ***Cyathea manniana****, Cylicomorpha parviflora, Diospyros abyssinica, Fleroya rubrostipulata, Macaranga capensis, Myrianthus holstii, Ochna holstii, Ocotea usambarensis, Olea capensis,* ***Podocarpus latifolius****, Pouteria adolfi-friedericii,* ***Prunus africana****, Strombosia scheffleri,* ***Syzygium guineense****, Tabernaemontana stapfiana and* ***Xymalos monospora***.

Generalist species expected to be present include ***Afrocarpus falcatus****, Agauria salicifolia, Albizia grandibracteata,* ***Albizia gummifera****, Albizia schimperiana,* ***Allophylus abyssinicus****, Allophylus africanus, Anthocleista grandiflora,* ***Apodytes dimidiata****, Balthasaria schliebenii,* ***Bersama abyssinica****, Bridelia brideliifolia, Carapa procera, Casearia battiscombei, Cassipourea malosana, Cassipourea ruwensorensis, Catha edulis,* ***Celtis africana****,* ***Clausena anisata****, Cornus volkensii,* ***Croton macrostachyus****, Croton sylvaticus,* ***Cussonia spicata****, Dombeya torrida, Dracaena steudneri,* ***Ehretia cymosa****,* ***Ekebergia capensis****, Euphorbia abyssinica, Ficus ovata,* ***Ficus sur****,* ***Ficus thonningii****,* ***Galiniera saxifraga****,* ***Hagenia abyssinica****, Harungana madagascariensis, Ilex mitis, Kigelia moosa,* ***Lepidotrichilia volkensii****,* ***Maesa lanceolata****, Maytenus acuminata,* ***Neoboutonia macrocalyx****,* ***Nuxia congesta****,* ***Ocotea kenyensis****,* ***Olea europaea (Olea europaea subsp. africana)****,* ***Pittosporum viridiflorum****,* ***Polyscias fulva****, Pouteria altissima,* ***Psychotria mahonii****, Psydrax parviflora,* ***Rapanea melanophloeos****,* ***Rhamnus prinoides****,* ***Schefflera abyssinica****, Schefflera volkensii, Shirakiopsis elliptica, Sinarundinaria alpina, Synsepalum brevipes, Syzygium cordatum, Tabernaemontana pachysiphon,* ***Vachellia abyssinica****,* ***Vachellia lahai****, Vepris nobilis, Vitex fischeri, Zanthoxylum gilletii* and *Zanthoxylum rubescens*.

Marginal species expected to be present include *Afrocarpus usambarensis, Alchornea hirtella, Berberis holstii, Blighia unijugata, Celtis gomphophylla,* ***Cordia africana****,* ***Croton megalocarpus****, Discopodium penninervium,* ***Dodonaea viscosa*** **var*****. angustifolia****, Dovyalis abyssinica,* ***Dovyalis macrocalyx****, Dracaena fragrans, Cassine buchananii, Embelia schimperi,* ***Ensete ventricosum****, Eugenia capensis, Fagaropsis angolensis, Ficus exasperata,* ***Ficus natalensis****, Garcinia buchananii,* ***Hypericum revolutum****, Landolphia buchananii, Manilkara butugi,* ***Maytenus undata****, Milicia excelsa, Millettia dura, Newtonia buchananii, Nuxia floribunda, Olinia rochetiana, Peddiea africana, Phoenix reclinata,* ***Phytolacca dodecandra****, Pleiocarpa pycnantha,* ***Pterolobium stellatum****, Rauvolfia caffra, Rinorea angustifolia, Ritchiea albersii, Rothmannia urcelliformis, Rubus apetalus, Sambucus ebulus,* ***Scutia myrtina****, Smilax anceps,* ***Solanecio mannii****, Solanum aculeastrum, Trema orientalis, Trichilia dregeana, Vangueria apiculata,* ***Vernonia auriculifera*** and *Vernonia myriantha.*

3.6.3. Afromontane undifferentiated forest (Fb)

This vegetation type encompasses a total area of 33,883 km^2, 4.60% of which is explicitly designated for biodiversity, species or landscape protection and 28.50% of which is designated for both protection and sustainable use objectives (Table 2).

Afromontane undifferentiated forest is usually shorter than Afromontane rain forest and despite some floristic overlap of characteristic species (e.g., ***Podocarpus latifolius***, ***Prunus africana*** and ***Xymalos monospora***), a distinctive difference in composition exists (Kindt *et al.* 2015, van Breugel *et al.* 2015a, van Breugel *et al.* 2015b). Afromontane undifferentiated forest usually replaces Afromontane rain forest at altitudes between 1250 and 2500 m asl on the drier slopes of mountains and at higher altitudes on the wetter slopes (and sometimes at lower altitudes) (Kindt *et al.* 2015, van Breugel *et al.* 2015a, van Breugel *et al.* 2015b, White 1983).

The two sub-types of Afromontane undifferentiated forest relevant to the Local Assessment Area are:

- **Afromontane single-dominant *Juniperus procera* forest (Fbj)** generally occurs on drier mountain slopes between 1800 and 2900 m asl and although they often form dense forests, it is a strong light-demander and does not regenerate in its own shade. Its presence is largely dependent on fire. Scattered individuals were observed in forest systems close to Nakuru and Naivasha.
- **Afromontane single-dominant *Hagenia abyssinica* forest (Fd)** generally occurs as almost pure stands of 9 to 15 m tall individuals between montane forest, thickets and shrubland at altitudes of 1800 to 3400 m asl.

Characteristic plant species expected are ***Afrocarpus falcatus***, ***Apodytes dimidiata***, *Cassipourea malosana*, ***Ekebergia capensis***, ***Halleria lucida***, *Ilex mitis*, ***Juniperus procera***, ***Nuxia congesta***, *Nuxia floribunda*, ***Ocotea kenyensis***, ***Olea europaea***, *Olinia rochetiana*, ***Podocarpus latifolius***, ***Prunus africana***, ***Rapanea melanophloeos***, *Vepris nobilis* and ***Xymalos monospora***.

Generalist species expected to be present include ***Acokanthera schimperi***, *Agauria salicifolia*, ***Albizia gummifera***, ***Allophylus abyssinicus***, *Berberis holstii*, ***Bersama abyssinica***, ***Buddleja polystachya***, ***Carissa spinarum***, *Catha edulis*, ***Celtis africana***, ***Clausena anisata***, *Clerodendrum myricoides*, *Cornus volkensii*, ***Croton macrostachyus***, ***Cussonia holstii***, ***Cussonia spicata***, *Diospyros abyssinica*, *Discopodium penninervium*, ***Dodonaea viscosa* var. *angustifolia***, *Dombeya torrida*, ***Dovyalis abyssinica***, *Dracaena steudneri*, ***Ehretia cymosa***, *Erica arborea*, ***Erythrina abyssinica***, ***Euclea divinorum***, *Euclea racemosa*, *Euphorbia abyssinica*, ***Euphorbia tirucalli***, *Faurea saligna*, *Ficus ovata*, ***Ficus sur***, ***Ficus thonningii***, ***Galiniera saxifraga***, ***Hagenia abyssinica***, ***Hypericum revolutum***, ***Lepidotrichilia volkensii***, ***Maesa lanceolata***, *Margaritaria discoidea*, ***Maytenus undata***, ***Myrsine africana***, *Olea capensis*, ***Pittosporum viridiflorum***, ***Pterolobium stellatum***, ***Rhamnus prinoides***, ***Rhoicissus tridentata***, *Ritchiea albersii*, *Schefflera volkensii*, ***Schrebera alata***, ***Searsia natalensis***, ***Senna didymobotrya***, *Sinarundinaria alpina*, ***Syzygium guineense***, ***Vachellia abyssinica***, ***Vachellia lahai***, *Vangueria madagascariensis*, *Vernonia amygdalina* and ***Zanthoxylum usambarense***.

Marginal species expected to be present include *Blighia unijugata*, ***Cordia africana***, ***Croton megalocarpus***, ***Dovyalis macrocalyx***, *Fagaropsis angolensis*, *Hypericum roeperianum*, *Lannea fulva*, *Maytenus acuminata*, *Mimusops kummel*, *Osyris lanceolata*, *Phoenix reclinata*, ***Phytolacca dodecandra***, ***Psydrax schimperiana***, *Rothmannia urcelliformis*, *Rubus apetalus*, *Rubus volkensii*, ***Schefflera abyssinica***, ***Scutia myrtina***, *Searsia longipes*, ***Searsia pyroides***, *Shirakiopsis elliptica*, ***Solanecio mannii***, *Syzygium cordatum*, *Trema orientalis*, ***Vangueria apiculata*** and *Vernonia myriantha*.

3.6.4. Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd)

This vegetation type encompasses a total area of 48,865 km^2, 10.60% of which is explicitly designated for biodiversity, species or landscape protection and 6.70% of which is designated for both protection and sustainable use objectives (Table 2).

This vegetation type is drainage-impeded or found on seasonally flooded soils. Where estimated tree cover is > 10%, the vegetation is classified as edaphic woody grasslands while the remainder is classified as edaphic grasslands. Characteristic species are ***Vachellia drepanolobium*** and ***Vachellia seyal***. Other species frequently encountered include *Balanites aegyptiaca*, *Borassus aethiopum*, *Combretum adenogonium*, *Commiphora schimperi*, *Dalbergia melanoxylon*, ***Faidherbia albida***, *Hyphaene compressa*, *Lannea humilis*, *Microchloa indica*, *Oryza longistaminata*, *Piliostigma thonningii*, *Sclerocarya birrea*, *Senegalia mellifera*, ***Senegalia polyacantha***, ***Senegalia senegal***, *Senegalia tanganyikensis*, *Setaria incrassata*, *Terminalia spinosa*, *Terminalia stuhlmannii*, *Thespesia danis*, ***Vachellia gerrardii***, *Vachellia malacocephala*, ***Vachellia nilotica***, *Vachellia paolii*, *Vachellia pseudofistula*, ***Vachellia sieberiana***, *Vachellia tortilis*, ***Vachellia xanthophloea*** and *Vachellia zanzibarica*,.

3.6.5. Evergreen and semi-evergreen bushland and thicket (Be)

This vegetation type encompasses a total area of 71,708 km², 8.90% of which is explicitly designated for biodiversity, species or landscape protection and 7.30% of which is designated for both protection and sustainable use objectives (Table 2).

This vegetation types occurs on drier slopes of mountains and upland areas, often forming an ecotone between Afromontane forest and deciduous bushland, in areas where the mean annual rainfall is between 500 – 850 mm.

Characteristic plant species expected are ***Acokanthera oppositifolia***, ***Acokanthera schimperi***, *Allophylus africanus*, ***Aloe kedongensis***, ***Aspilia mossambicensis***, *Azima tetracantha*, ***Calodendrum capense***, *Canthium keniense*, *Capparis fascicularis*, ***Capparis tomentosa***, ***Carissa spinarum***, *Cassine buchananii*, *Cissus quadrangularis*, *Cissus rotundifolia*, ***Croton dichogamus***, ***Cussonia holstii***, ***Dodonaea viscosa* var. *angustifolia***, ***Dombeya burgessiae***, *Dracaena ellenbeckiana*, *Drypetes gerrardii*, ***Erythrococca bongensis***, ***Euclea divinorum***, *Euclea racemosa*, ***Euphorbia candelabrum***, ***Gnidia subcordata***, ***Grewia bicolor***, ***Grewia similis***, *Grewia tembensis*, ***Gymnosporia heterophylla***, ***Juniperus procera***, ***Maerua triphylla***, ***Olea europaea***, ***Psiadia punctulata***, ***Psydrax schimperiana***, ***Pterolobium stellatum***, ***Sarcostemma viminale***, ***Schrebera alata***, ***Scutia myrtina***, ***Searsia natalensis***, ***Senegalia brevispica***, ***Senegalia senegal***, ***Tarchonanthus camphoratus***, *Tarenna graveolens*, ***Tinnea aethiopica***, *Turraea mombassana*, *Turraea nilotica*, ***Vachellia drepanolobium***, ***Vachellia gerrardii***, ***Vachellia hockii***, *Vachellia kirkii*, ***Vachellia seyal***, *Vepris nobilis*, ***Vepris simplicifolia***, *Vepris trichocarpa* and ***Vernonia brachycalyx***.

Generalist species expected to be present include *Albizia coriaria, Berberis holstii, Berchemia discolor, Bridelia scleroneura, Cadaba farinosa, Canthium lactescens, Catha edulis, Clerodendrum myricoides, Dichrostachys cinerea*, ***Euphorbia tirucalli***, *Grewia mollis, Harrisonia abyssinica*, ***Pappea capensis***, ***Pistacia aethiopica***, ***Pittosporum viridiflorum***, ***Rhoicissus tridentata***, *Senegalia mellifera*, ***Vangueria apiculata***, *Vangueria madagascariensis*, ***Zanthoxylum usambarense*** and *Ziziphus abyssinica*.

Marginal species expected to be present include *Albizia amara, Albizia zygia, Allophylus rubifolius, Annona senegalensis, Antidesma venosum*, ***Apodytes dimidiata***, *Balanites aegyptiaca, Boscia angustifolia, Bridelia micrantha*, ***Clausena anisata***, *Combretum molle, Commiphora africana*, ***Cordia monoica***, ***Crotalaria agatiflora***, ***Croton macrostachyus***, *Cussonia arborea, Dombeya rotundifolia, Dovyalis abyssinica*, ***Erythrina abyssinica***, *Faurea rochetiana, Faurea saligna, Ficus glumosa, Flacourtia indica, Gardenia ternifolia, Indigofera swaziensis, Lannea fulva, Lannea humilis, Lannea schweinfurthii, Lecaniodiscus fraxinifolius*, ***Lippia kituiensis***, *Gymnosporia senegalensis*, ***Maytenus undata***, ***Oncoba spinosa***, *Ormocarpum kirkii, Osyris lanceolata, Ozoroa insignis, Pavetta crassipes, Rhamnus staddo, Rhoicissus revoilii*, ***Searsia pyroides***, ***Senegalia polyacantha***, ***Senna didymobotrya***, *Solanecio cydoniifolius*, ***Solanecio mannii***, *Steganotaenia araliacea, Stereospermum kunthianum, Strychnos henningsii, Terminalia brownii, Tetradenia riparia*, ***Vachellia lahai***, ***Vachellia nilotica***, ***Vangueria infausta***, *Zanthoxylum chalybeum, Ziziphus mucronata* and *Ziziphus pubescens*.

3.6.6. Halophytic vegetation (Z)

This vegetation type encompasses a total area of 6,087 km², 16.70% of which is explicitly designated for biodiversity, species or landscape protection and 9.10% of which is designated for both protection and sustainable use objectives (Table 2).

This unit represent a small group of plants that can grow on saline soils typically found along the Rift Valley lake systems. Characteristic species found around these lakes are ***Cyperus laevigatus***, ***Sporobolus spicatus*** and *Sueda monoica*. Other species expected are *Drake-brockmania somalensis, Leptochloa fusca, Salsola africana, Salvadora persica*, ***Sesbania sesban***, *Sporobolus robustus* and *Triplocephalum holstii*.

3.6.7. Riverine wooded vegetation (R)

This vegetation type encompasses a total area of 7,955 km², 10.00% of which is explicitly designated for biodiversity, species or landscape protection and 12.40% of which is designated for both protection and sustainable use objectives (Table 2).

Typical species expected in larger drainage systems include *Diospyros mespiliformis*, ***Ficus sycomorus***, ***Syzygium guineense*** and *Trichilia emetica*. However, many species from adjacent vegetation types that river systems run through can also be expected within the riparian zone and along the fringes.

3.6.8. Upland *Acacia* wooded grassland (We)

This vegetation type encompasses a total area of 19,259 km², 15.60% of which is explicitly designated for biodiversity, species or landscape protection and 5.20% of which is designated for both protection and sustainable use objectives (Table 2).

It is often the case that *Vachellia/Senegalia* (*Acacia*) *spp.* exhibit invader characteristics as a result of over- stocking and utilization by domestic (or wild) herbivores, which transform other vegetation types e.g., Evergreen and semi-evergreen bushland and thicket (Be). This vegetation type is dominated by *Vachellia/Senegalia spp.*, which commonly occur together with evergreen species such as ***Carissa edulis***, ***Dodonaea viscosa* var. *angustifolia***, ***Euclea divinorum***, *Euclea racemosa* and ***Tarchonanthus camphoratus*** often because of habitat transformation (Kindt *et al.* 2015, van Breugel *et al.* 2015a, van Breugel *et al.* 2015b, White 1983).

Characteristic plant species expected are ***Acokanthera schimperi***, ***Capparis tomentosa***, ***Carissa spinarum***, ***Cussonia holstii***, ***Dodonaea viscosa* var. *angustifolia***, *Cassine buchananii*, ***Euclea divinorum***, *Euclea racemosa*, ***Euphorbia candelabrum***, ***Grewia bicolor***, ***Grewia similis***, ***Pterolobium stellatum***, ***Schrebera alata***, ***Scutia myrtina, Searsia natalensis***, ***Senegalia senegal***, *Tarenna graveolens*, ***Vachellia drepanolobium***, ***Vachellia gerrardii***, ***Vachellia hockii***, *Vachellia kirkii* and ***Vachellia seyal***.

Generalist species expected to be present include *Albizia adianthifolia, Albizia amara, Combretum molle, Entada abyssinica*, ***Faidherbia albida***, *Gymnosporia senegalensis, Parinari curatellifolia,* ***Senegalia brevispica***, *Senegalia mellifera*, ***Senegalia polyacantha***, ***Vachellia sieberiana***, *Vachellia tortilis* and ***Vachellia xanthophloea***.

Marginal species expected to be present include *Allophylus rubifolius,* ***Bersama abyssinica***, *Boscia angustifolia, Boscia salicifolia, Commiphora habessinica,* ***Cordia africana***, *Cussonia arborea, Dichrostachys cinerea, Dombeya rotundifolia,* ***Erythrina abyssinica***, ***Erythrina burttii***, *Ficus glumosa, Gardenia ternifolia, Grewia tembensis, Lannea fulva, Lannea humilis, Lannea schimperi, Lannea schweinfurthii, Ozoroa insignis,* ***Pappea capensis***, ***Senna didymobotrya***, *Terminalia brownii,* ***Vangueria infausta***, *Ximenia americana, Ziziphus abyssinica* and *Ziziphus mucronata*.

3.6.9. Freshwater swamp (X)

The Freshwater swamp (X) vegetation type comprises the terrestrial component of the Water bodies (w) habitat type. This vegetation type encompasses a total area of 29,189 km², 20.80% of which is explicitly designated for biodiversity, species or landscape protection and 7.50% of which is designated for both protection and sustainable use objectives (Table 2).

This vegetation type occurs in depressions where water permanently floods the surface to a shallow depth, while seasonal swamps are usually covered with edaphic grassland (White 1983). They consist of a wide belt of reed-swamp, where the dominant species are usually rooted in the soil with stems that rise above the water.

An expected characteristic plant species is ***Cyperus papyrus***. Generalist species expected to be present include *Aeschynomene cristata, Aeschynomene elaphroxylon, Aeschynomene pfundii, Aeschynomene schimperi,* *Cissampelos mucronata*, ***Cyperus latifolius***, *Echinochloa stagnina, Heterotis rotundifolia*, ***Leersia hexandra***, *Miscanthus violaceus, Nymphaea lotus, Nymphaea nouchali, Oryza longistaminata, Pennisetum macrourum, Persicaria decipiens, Phoenix reclinata*, ***Phragmites australis***, ***Pycreus mundtii***, ***Sesbania sesban***, *Syzygium cordatum, Typha domingensis* and ***Typha latifolia***.

Marginal species expected to be present include *Aeschynomene abyssinica, Ceratophyllum demersum, Echinochloa pyramidalis*, ***Eichhornia crassipes***, *Ficus verruculosa, Hibiscus diversifolius, Ipomoea rubens, Kotschya africana, Lemna perpusilla, Loudetia phragmitoides, Ludwigia octovalvis, Ludwigia adscendens*, ***Melanthera scandens***, *Mikania capensis, Sesbania bispinosa, Utricularia gibba*, ***Vachellia xanthophloea***, *Vigna luteola, Voacanga thouarsii* and *Vossia cuspidata*.

4. METHODS

4.1. General field methodology

A multistage, stratified, semi-random sampling (MSSRS) approach (Bourgeron *et al.* 2001) was applied to ensure representativeness of sampling in the landscape. The approach is recommended and considered as most efficient when large areas need to be sampled in a short time and with limited resources (Bourgeron *et al.*, 2001). This approach considers the inherent complexity to investigate a regional scale survey area in depth within budgetary and time constraints (considering accessibility and site complexity) and instead requires that a stratified and representative subset area representing at least 5% of the global area be visited in detail. The subset area must be selected to represent broad variations that can be expected from the global study area. Within this subset area an intensive sampling effort (high number of observations) can take place that should also be designed to be representative of the range of variations found within the global study area (Morris & Emberton 2009; Greenwood & Robinson 2006). The MSSRS approach for large scale studies such as integrated regional ecological assessments have been reviewed by Bourgeron *et al.* (2001) and considered to be the best or most suited for:

- Representativeness of the sampled area,
- Representativeness of the variability within the sample area,
- Highest power for interpolation / extrapolation from a limited numbers of samples,
- High-cost benefit ratio for studying large areas,
- Highest efficiency for pattern recovery for large areas of low to high diversity.

The approach followed in this study further consisted of undertaking a large number of survey sites, each with a small area, instead of the more traditional small number of survey sites over a larger area each. Provided the number of sample sites is high, the capacity of this method to detect rare species is similar to that of methods using a larger sample site size (Bourgeron *et al.* 2001; Newton 2007). A further advantage of the proposed approach when many plots are undertaken lies in its ability to rapidly provide a greater insight into local level variability (Newton 2007), which a few larger sized plots does not provide (Kent 2012) unless substantial time is invested into the survey effort.

A total of 219 sample plots were assessed over three sampling periods; 38 of which were assessed over six days during the biodiversity reconnaissance survey (14 - 21 November 2020), 90 sample plots assessed over 10 days of fieldwork during the dry season survey (17 - 26 February 2021) and 91 sample plots assessed over 12 days of fieldwork during the wet season survey (13 - 25 April 2021).

Sample plots were generally 25 m x 25 m square but adjusted to terrain features along streams or river courses where plot size was 60 m x 10 m. A GPS reading was taken at the starting point of the plot cutline. Vegetation surveys were conducted following the Zürich-Montpellier (Braun-Blanquet) School of total floristic composition (Werger 1974).

At each sample plot the following assessments were made:

- Floristic assessment: all plant species were recorded (trees, shrubs, grasses, sedges, ferns, forbs, geophytes, succulents and aliens/exotics) and a cover value, following the Braun-Blanquet cover/abundance scale (Mueller-Dombois & Ellenberg 1974), allocated to each species.
- Structural assessment: estimates were made for the total woody cover as well as the cover and mean plant height of the following layers: > 20 m woody layer (high trees), 11 - 20 m woody layer (tall trees), 6 - 10 m woody layer (short trees), 2 - 5 m woody layer (low trees), grass layer, non-grassy herbaceous plants (forb layer), bamboos, orchids, lichen, moss, fungi and litter/detritus.
- Carbon assessment: stem diameter (at breast height) and tree height were recorded for all woody individuals, with a stem diameter of > 10 cm, within the sample plot (see carbon report).
- Habitat assessment: habitat features such as topography; aspect (cardinal direction that a terrain surface faces); slope; degree of erosion; clay content of the soil; pebble, stone, rock and boulder cover; litter depth, presence of streams or water courses, were recorded.
- Site quality assessment: transformation, fragmentation as well as regeneration status/mode were evaluated.
- Environmental assessment: light (lux), temperature (°C), noise (decibel), humidity (%) and cloud cover were measured at the time of the surveys. Since these parameters vary depending on the time of day and also seasonally, mean values are not easily compared among associations.
- Animal assessment: any signs of birds, mammals, reptiles, amphibians, insects or fish were noted.
- Additionally, any signs of human influence or natural resource use were noted.

4.2. General analytical methodology

Broad habitat types identified during the field surveys and annotated on the field reconnaissance maps were used as a reference during the field work period. After the field season, the location of the points sampled were checked for their position in relation to the VECEA work by Van Breugel *et al.* (2015). The data were then summarised by the corresponding VECEA broad habitat types.

The approach followed represents a guided qualitative and quantitative habitat descriptions and are sufficient for:

- Placing a plant or animal or event in a known, easily understood setting.
- Producing a stratification of an area by vegetation type in relation to known and established prior work.
- Looking for trends in the way animals use different habitat types, for example from animal surveys which do not include detailed vegetation analysis;
- Achieving a standard set of terms to use when discussing the different parts of the habitat.

4.3. Field work limitations

In some cases, it was not possible to survey sample plots that occurred within the boundaries of fenced/private land. In such instances a suitable representative area in close vicinity was selected to undertake the survey.

4.4. Data analysis

4.4.1. Species accumulation curves

Species accumulation curves (SAC) for all data points were generated for the wet season and dry season surveys separately, as well as combined. Sampling sufficiency was determined by establishing whether the point had been reached where a line representing one new sample adding one new species was tangent to the curve (Brewer & McCann 1982). Moreno and Halffter (2001) proposed that a satisfactory level of completeness would have been attained if 90% of the total fauna (flora in this study) predicted by their models would have been reached. Their model is based on the Michaelis-Menten equation (Soberôn & Llorente 1993) and therefore also used in this study to determine a predicted species total. The actual number of species encountered were then expressed as a percentage of the predicted number of species to determine sampling sufficiency.

4.4.2. Classification of the floristic data

Due to the high levels of disturbance/degradation across the Local Assessment Area it was not deemed feasible to classify the floristic data using TURBOVEG and JUICE computer programs (Hennekens & Schaminee 2001; Tichy 2002) as the results would not reveal distinct plant communities. Instead, the data were processed and analysed using Microsoft® Excel® for Microsoft 365 MSO (16.0.14026.20202), where the data of each sample plot were extracted against VECEA predicted habitat type and land cover. Plant communities associated with each VECEA unit were represented by dominant and characteristic species with a frequency occurrence ≥ 40% across all sample plots within each VECEA unit, as well as species of conservation concern.

4.4.3. IUCN Listed species or species with special status or special search request

Species are classified according to the IUCN Red List into the following nine groups, based on rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation:

- **Extinct (EX)** – No known individuals remaining.
- **Extinct in the Wild (EW)** – Known only to survive in captivity, or as a naturalized population outside its historic range.
- **Critically Endangered (CR)** – Extremely high risk of extinction in the wild.
- **Endangered (EN)** – High risk of extinction in the wild.
- **Vulnerable (VU**) – High risk of endangerment in the wild.
- **Near Threatened (NT)** – Likely to become endangered in the near future.
- **Least Concern (LC)** – Lowest risk. Does not qualify for a more at risk category. Widespread and abundant taxa are included in this category.
- **Data Deficient (DD)** – Not enough data to assess its risk of extinction.
- **Not Evaluated (NE)** – Has not yet been evaluated against the criteria.

Threatened species are considered useful indicators of the health of an ecosystem. The term "threatened" used in context refers to a grouping of three categories: Critically Endangered, Endangered, and Vulnerable. Endangered species are considered to be species in danger of extinction, while vulnerable species are considered likely to move into the endangered category in the near future. Rare species are those species that occur in relatively low numbers or densities and in many cases have specialised habitat requirements. These rare species are usually localized within geographical areas or thinly scattered over an extensive range.

Very few plants (1565 species) for Kenya have been evaluated based on the IUCN Red List criteria as indicated by this data sourced[2]. Based on the IUCN criteria for threatened taxa, 27 species are Critically Endangered, 127 species are Endangered, 170 species are Vulnerable, 63 species are Near Threatened, and 22 species are considered Data Deficient. Two threatened species i.e., *Ansellia africana* (VU) and *Prunus africana* (VU) and a single near threatened species i.e. *Euphorbia bussei* were recorded. *Ocotea kenyensis* (VU) was not recorded in a sampling plot but was encountered while tracking during the reconnaissance survey.

Based on IUCN limitations other species of botanical significance such as *Lagarosiphon hydrilloides* and *Ethulia schefflera* occurrence were included in this evaluation.

The best references currently available includes Kenya Trees, Shrubs and Lianas (Beentje 1994), Upland Kenya Wild Flowers and Ferns (Agnew 2013), a Field guide to common Trees and Shrubs of East Africa (Dharani 2002), a Field guide to Acacias of East Africa (Dharani 2006) and Collins Guide to Wild Flowers of East Africa (Blundell 1987). Additional reference material on the distribution of plants is sourced from other studies conducted in Kenya.

[2] IUCN Red List for plants. Accessed December 2020. https://www.iucnredlist.org/

4.4.4. Assessment of habitat degradation, fragmentation and quality

A degradation assessment was conducted based on environmental modelling guidelines promulgated by Pianosi *et al.* (2016) and an adaptation of the model by Elliott *et al.* (2013). The evaluation considers a range of variables that contribute to habitat restoration and their actual condition in relation to a theoretical high integrity state. Based on how far from the ideal high integrity state the field score is, the habitat degradation can be inferred and the potential of the habitat to "bounce back" can be considered. Generally, if the scores are >2 the potential to bounce back is high, while below that, the likelihood of a slow bounce is high, with limited chances of a recovery to the original habitat type through succession, as disturbance is likely to drive succession to an alternate state.

A fragmentation assessment was conducted based on environmental modelling guidelines promulgated by Pianosi *et al.* (2016) and an adaptation of the model by Elliott *et al.* (2013). The number of sites in each class and the mean score for each class are then used to define the fragmentation level prevalent for the habitat type.

A guided subjective ranking, using a scale of 1 to 5 to rank each class of habitat quality deemed adequate to describe the site visited (5 being higher quality than 1) this assists the determination of ecological quality.

5. RESULTS

5.1. Sampling sufficiency and species accumulation curves

5.1.1. Spatial sampling overview

A total of 36% of the 980 grid cells encompassing the Local Assessment Area were investigated through the body of work conducted during the dry and wet season surveys. Approximately 15% of the sampling grid cells were physically sampled (i.e., at least one sampling site was conducted within the grid cell) and ca. 21% were "tracked" (i.e., these sampling grid cells were visited during the study thereby providing the investigation team a chance to validate desk-based information) (Figure 6).

As the preliminary targets stated an objective of sampling a minimum of 5% and an optimal target of 10% of the sampling grid cells in the Local Assessment Area, the sampling effort is deemed sufficient from a spatial perspective and is considered to have provided the research team a fair overview of the Local Assessment Area's habitat types and associated vegetation.

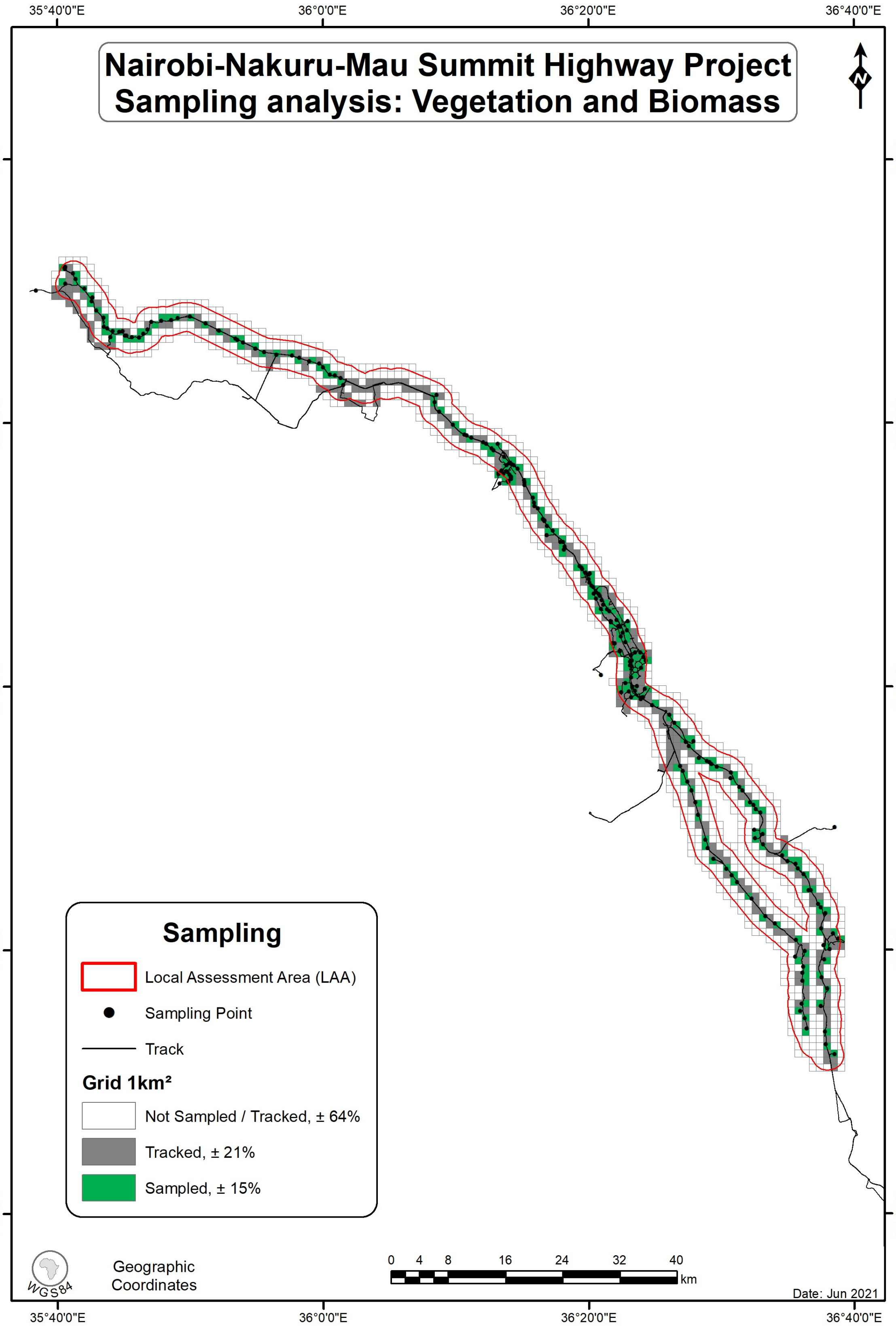


Figure 6: Spatial sampling sufficiency overview for the Local Assessment Area.

5.1.2. Sampling parameters

Sampling was conducted during the dry and wet season surveys at 181 survey sites over a total area of 108,600.0 m^2 (10.9 ha) at a mean altitude of 2,066.4 m asl. The mean of the radius of validity for status noted (this metric highlights how far from the actual sample site the situation noted on the relevé is perceived to be valid) was 62.0 m (Table 3). The radius of validity metric highlights that based on the actual area sampled, the validity of the work was deemed as confirmed over an area of +/- 133.0 ha, within which the 10.9 ha area actually sampled were located.

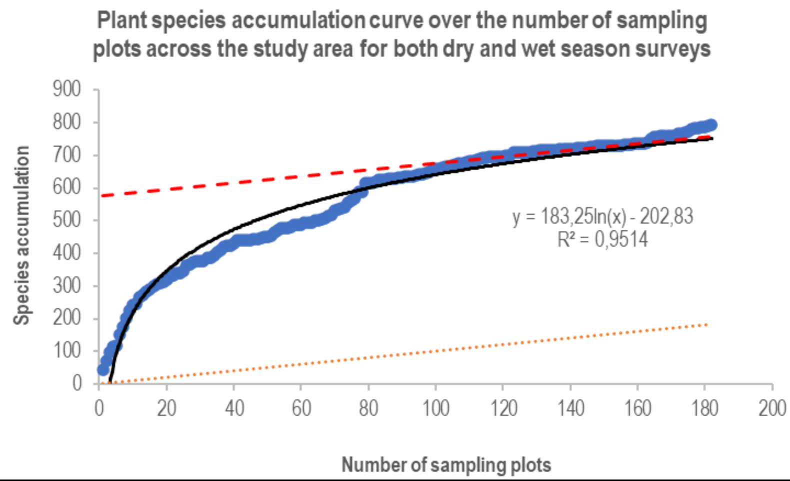
Table 3: General parameters of survey site locations along the Nairobi-Nakuru-Mau Summit Highway Project

Habitat types (VECEA)	Number of sites sampled in 2021*	Area sampled (in (m^2)	Area sampled in ha	Mean of Altitude (m) for the sites sampled	Mean of Radius of validity for status noted
Afromontane bamboo	5	3,000.0	0.3	2,609.8	50.0
Afromontane rain forest	2	1,200.0	0.1	2,409.0	25.0
Afromontane undifferentiated forest	52	31,200.0	3.1	2,286.1	55.8
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	3	1,800.0	0.2	2,540.3	75.0
Evergreen and semi-evergreen bushland and thicket	87	52,200.0	5.2	1,951.9	66.4
Halophytic vegetation	5	3,000.0	0.3	1,790.2	85.0
Riverine wooded vegetation	21	12,600.0	1.3	1,875.9	63.1
Upland Acacia wooded grassland	5	3,000.0	0.3	1,942.6	50.0
Water bodies	1	600.0	0.1	1,781.0	25.0
Grand Total	181	108,600.0	10.9	2,066.4	62.0

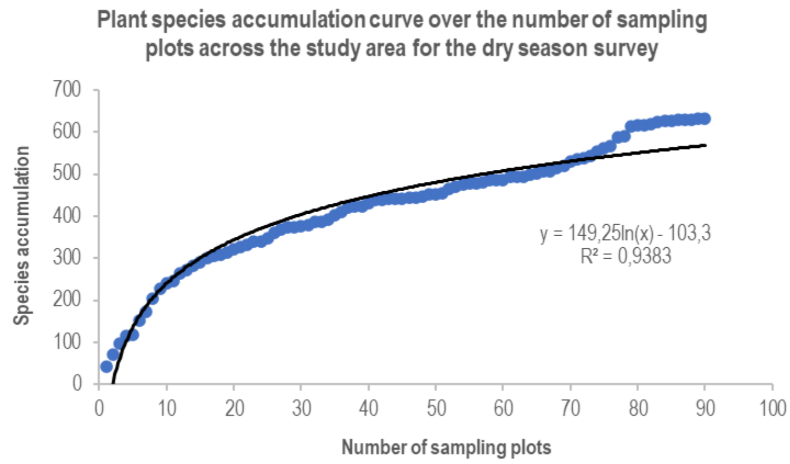
5.1.3. Species accumulation curves for the study area

A total of 889 taxa were recorded across the Regional Assessment Area during the reconnaissance, dry and wet season surveys (219 sampling plots). The reconnaissance visit surveys, due to their different nature and purpose were not included in the species accumulation curve pattern.

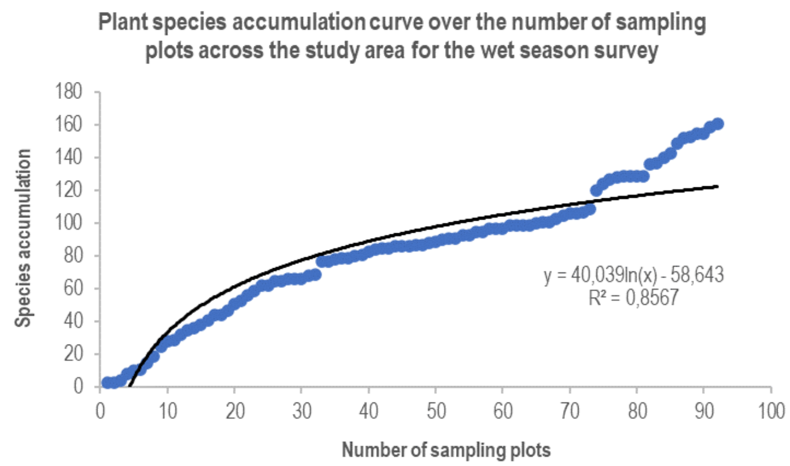
The species accumulation curve for all sample plots surveyed during the dry and wet seasons combined (181 plots, $R^2 = 0.95$) reached an asymptote, and the point where a line representing one new sample adding one new species was tangent to the curve had been reached approximately after 180 sample plots (Figure 7). When assessed for the dry (R^2 =0.93) and wet (R^2 =0.85) season surveys separately, it is noted that after approximately 90 sampling plots the number of species added was still increasing well above the point of one new sample plot adding one new species.



a)



b)



c)

Figure 7: Species accumulation curve of plant species recorded across sampling plots along the Nairobi-Nakuru-Mau Summit Highway Project during the dry and wet season surveys combined (a), as well as separately for the dry (b) and wet seasons (c).

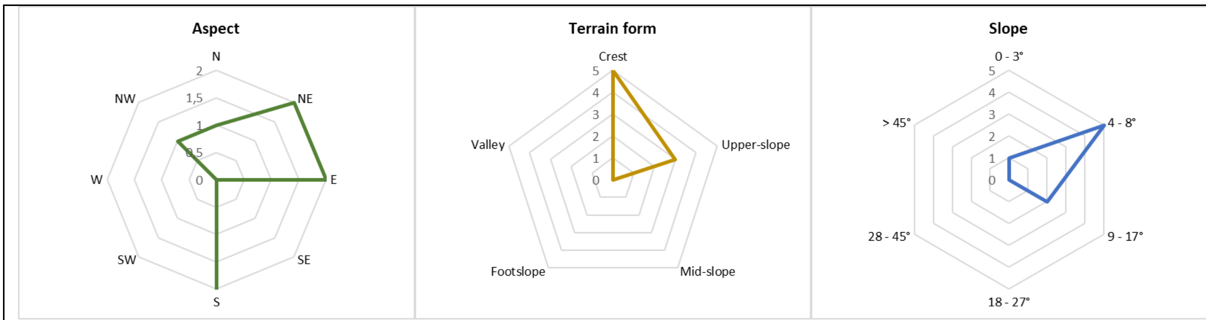
5.2. Description of the habitat types

5.2.1. Afromontane bamboo (B)

5.2.1.1. Location and environmental features

Sampling plots within the Afromontane bamboo (B) habitat type occurred at an altitude ranging from 2548 to 2673 m asl (mean 2618 m asl). The aspect was generally from east to north-east, with north-west and southern slopes also featuring. Crest and upper-slope were the dominant terrain form, with gradual (4 – 8°) to moderate (9 – 17°) inclines (Table 4). The mean percentage cover of rock, sand and grit (pebbles, stones, rocks, boulders and exposed bare rock) was 0%.

Table 4: Summary of the dominant environmental features of the Afromontane bamboo (B) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)		
	Overall rock, sand and grit	**0.0**
	Pebbles	0.0
	Stones	0.0
	Rocks	0.0
	Boulders	0.0
	Exposed bare rock	0.0

5.2.1.2. Floristic composition

The following species had an occurrence of ≥ 40% across all sample plots in the Afromontane bamboo (B) habitat type: *Oxalis corniculata*, *Centella asiatica*, *Urtica massaica*, *Achyrospermum schimperi*, *Juniperus procera*, *Kalanchoe densiflora*, *Pilea* cf. *johnstonii* and *Selaginella kraussiana*.

5.2.1.3. Vegetation structure

The dominant class for trees were the canopy trees, which had a mean height of 17.0 m and a mean percentage cover of 90.3% (Appendix II, Table A). The dominant class for shrubs were the high shrubs class, which had a mean height of 4.0 m and a mean percentage cover of 60.0% (Appendix II, Table B). The dominant class of grasses were the very high grasses, which had a mean height of 1.6 m (mean cover percentage = 60.0%) and the sub-dominant class were low level grasses, which had a mean height of 0.2 m (mean cover percentage = 57.0%) (Appendix II, Table C).

5.2.1.4. Plant diversity

Plant diversity in the Afromontane bamboo (B) was moderate-high. The mean number of species per sample plot for the eight plots surveyed was 23 species with a range from 7 to 52 species.

5.2.1.5. IUCN Red List species and endemic species

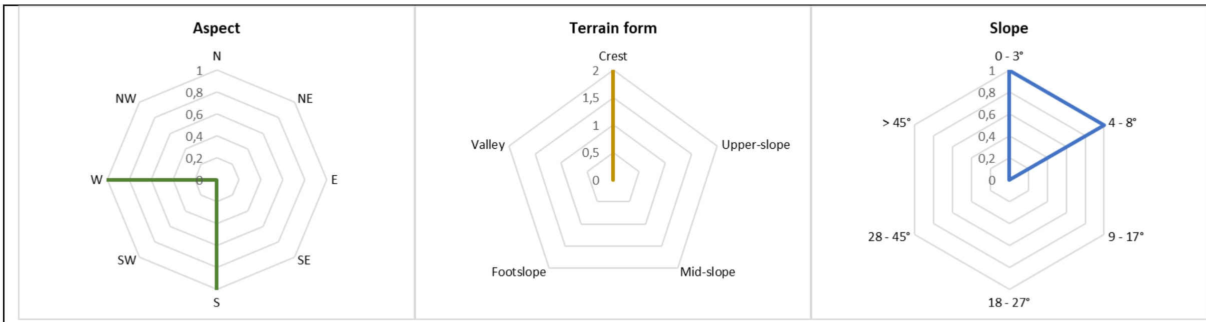
Prunus africana (Vulnerable) was recorded across 25% of the sampling plots in the Afromontane bamboo (B) habitat type. No endemic species were recorded.

5.2.2. Afromontane rain forest (Fa)

5.2.2.1. Location and environmental features

Sampling plots within the Afromontane rain forest (Fa) habitat type occurred at an altitude ranging from 2403 to 2421 m asl (mean 2412 m asl). The sampling plots surveyed had western and southern aspects and occurred on the crest with flat (0 - 3°) and gradual (4 - 8°) gradients (Table 5). The mean percentage cover of rock, sand and grit (pebbles, stones, rocks, boulders and exposed bare rock) was 0.0%.

Table 5: Summary of the dominant environmental features of the Afromontane rain forest (Fa) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)		
	Overall rock, sand and grit	**0.0**
	Pebbles	0.0
	Stones	0.0
	Rocks	0.0
	Boulders	0.0
	Exposed bare rock	0.0

5.2.2.2. Floristic composition

The following species had an occurrence of ≥ 40% across all sample plots in the Afromontane rain forest (Fa) habitat type: *Cestrum aurantiacum*, *Galinsoga parviflora, Gnaphalium unionis, Pennisetum clandestinum, Acanthus cf. pubescens, Achyrospermum schimperi, Acmella caulirhiza, Amaranthus hybridus, Bidens pilosa, Buddleja polystachya, Centella asiatica, Cirsium vulgare, Colocasia esculenta, Commelina benghalensis, Conyza bonariensis, Conyza subscaposa, Cupressus lusitanica, Cyathula cylindrica, Cynodon nlemfuensis, Dichondra repens, Dichrocephala integrifolia, Digitaria diagonalis, Emex australis, Ensete ventricosum, Eragrostis nindensis, Helichrysum foetidum, Helichyrusum forskahlii, Kalanchoe densiflora, Kyllinga alba, Lagenaria abyssinica, Leucas grandis, Micromeria imbricata, Oenothera parviflora, Oldenlandia scopulorum, Oxalis corniculata, Physalis peruviana, Pilea johnstonii, Poa leptoclada, Pycnostachys meyeri, Ricinus communis, Rubia cordifolia, Rubus scheffleri, Salvia nilotica, Sida tenuicarpa, Solanum anguivi, Solanum giganteum, Solanum mauritianum, Solanum campylacanthum, Sporobolus agrostoides, Stellaria media, Tagetes minuta, Trifolium semipilosum, Urena lobata* and *Zea mays.*

5.2.2.3. Vegetation structure

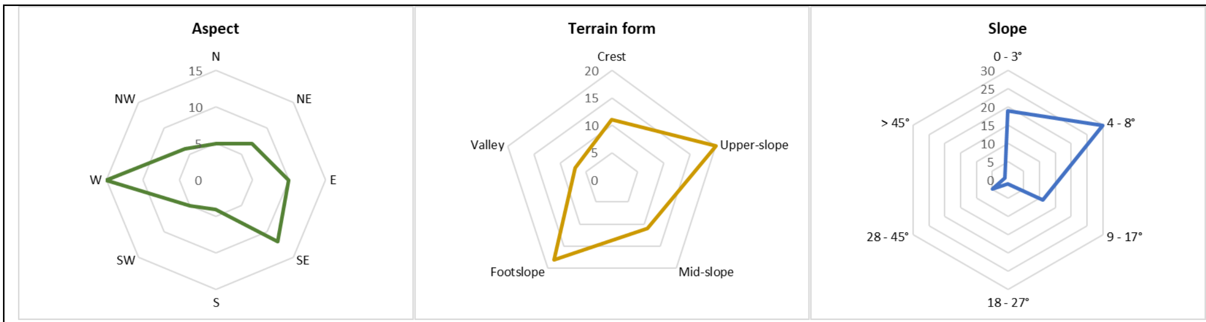
The dominant class for trees were the canopy trees, which had a mean height of 16.0 m and a mean percentage cover of 90.0% (Appendix II, Table A). The dominant class for shrubs were the medium shrubs class, which had a mean height of 3.0 m and a mean percentage cover of 40.0% (Appendix II, Table B). The dominant class of grasses were the low level grasses, which had a mean height of 0.2 m (mean cover percentage = 71.5%) and the sub-dominant class were very high grasses, which had a mean height of 1.6 m (mean cover percentage = 35.0%) (Appendix II, Table C).

5.2.2.4. Plant diversity
Plant diversity in the Afromontane rain forest (Fa) was moderate. The mean number of species per sample plot for the two plots surveyed was 29 species with a range from 27 to 31 species.

5.2.2.5. IUCN Red List species and endemic species
No IUCN Red List species or endemic species were recorded at sampling plots across the Afromontane rain forest (Fa) habitat type.

5.2.3. Afromontane undifferentiated forest (Fb)
5.2.3.1. Location and environmental features
Sampling plots within the Afromontane undifferentiated forest (Fb) habitat type occurred at an altitude ranging from 1816 to 2685 m asl (mean 2301 m asl). The aspect was predominantly west and south-east; but also varied between north, north-west, north-east, east, south and south-west. The terrain varied across the catenal gradient, where upper-slopes and foot-slopes were the dominant terrain form and crest, mid-slope and valley bottom terrain also featured. Slopes varied from flat (0 - 3°) to very steep (> 45°), with gradual (4 - 8°) slopes being the predominant gradient (Table 6). The mean percentage cover of rock, sand and grit was 4.2%, which was made up of pebbles (0.5%), stones (1.1%), rocks (1.4%), boulders (1.2%) and exposed bare rock (0.1%).

Table 6: Summary of the dominant environmental features of the Afromontane undifferentiated forest (Fb) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)	**Overall rock, sand and grit**	**4.2**
	Pebbles	0.5
	Stones	1.1
	Rocks	1.4
	Boulders	1.2
	Exposed bare rock	0.1

5.2.3.2. Floristic composition
The following species had an occurrence of ≥ 40% across all sample plots in the Afromontane undifferentiated forest (Fb) habitat type: *Oxalis corniculata, Bidens pilosa, Conyza bonariensis, Sida tenuicarpa and Pennisetum clandestinum*.

5.2.3.3. Vegetation structure
The dominant class for trees were the canopy trees, which had a mean height of 12.7 m (mean cover percentage = 42.3%) and the sub-dominant class were mid-canopy trees, which had a mean height of 9.1 m (mean cover percentage = 33.1%) (Appendix II, Table A). The dominant class for shrubs were the very high shrubs, which had a mean height of 6.0 m (mean cover percentage = 41.7%) and the sub-dominant class were high shrubs, which had a mean height of 4.6 m (mean cover percentage = 40.6%) (Appendix II, Table B). The dominant class of grasses were the low-level grasses, which had a mean height of 0.2 m (mean cover percentage = 53.1%) and the

sub-dominant class were very high grasses, which had a mean height of 1.7 m (mean cover percentage = 47.3%) (Appendix II, Table C).

5.2.3.4. Plant diversity

Plant diversity in the Afromontane undifferentiated forest (Fb) was moderate-high. The mean number of species per sample plot for the 67 plots surveyed was 35 species with a range from 6 to 82 species.

5.2.3.5. IUCN Red List species and endemic species

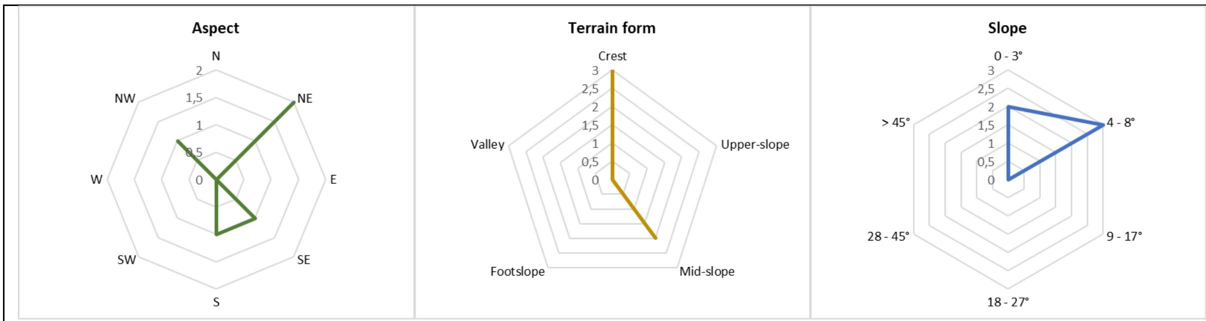
Prunus africana (Vulnerable) was recorded across 1% of the sampling plots in the Afromontane undifferentiated forest (Fb) habitat type. No endemic species were recorded.

5.2.4. Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd)

5.2.4.1. Location and environmental features

Sampling plots within the Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd) habitat type occurred at an altitude ranging from 2375 to 2664 m asl (mean 2504 m asl). The aspect was predominantly north-east but also featured south-east, south and north-west facing slopes on crest and mid-slope terrain, with flat (0 - 3°) to gradual (4 - 8°) gradients (Table 7). The mean percentage cover of rock, sand and grit (pebbles, stones, rocks, boulders and exposed bare rock) was 0.0%.

Table 7: Summary of the dominant environmental features of the Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)		
	Overall rock, sand and grit	**0.0**
	Pebbles	0.0
	Stones	0.0
	Rocks	0.0
	Boulders	0.0
	Exposed bare rock	0.0

5.2.4.2. Floristic composition

The following species had an occurrence of ≥ 40% across all sample plots in the Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd) habitat type: *Achyranthes aspera, Pennisetum clandestinum, Alchemilla kiwuensis, Bidens pilosa, Centella asiatica, Conyza bonariensis, Crassocephalum montuosum, Cynodon dactylon, Cyperus rigidifolius, Digitaria diagonalis, Eucalyptus ovata, Galinsoga parviflora, Oxalis corniculata* and *Senecio moorei.*

5.2.4.3. Vegetation structure

The dominant class for trees were the canopy trees, which had a mean height of 20.0 m and a mean percentage cover of 40.0% (Appendix II, Table A). The dominant class of grasses were the low-level grasses, which had a mean height of 0.2 m (mean cover percentage = 65.0%) and the sub-dominant class were medium grasses, which had a mean height of 0.9 m (mean cover percentage = 35.0%) (Appendix II, Table C).

5.2.4.4. Plant diversity

Plant diversity in the Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd) was moderate. The mean number of species per sample plot for the five plots surveyed was 24 species with a range from 12 to 35 species.

5.2.4.5. IUCN Red List species and endemic species

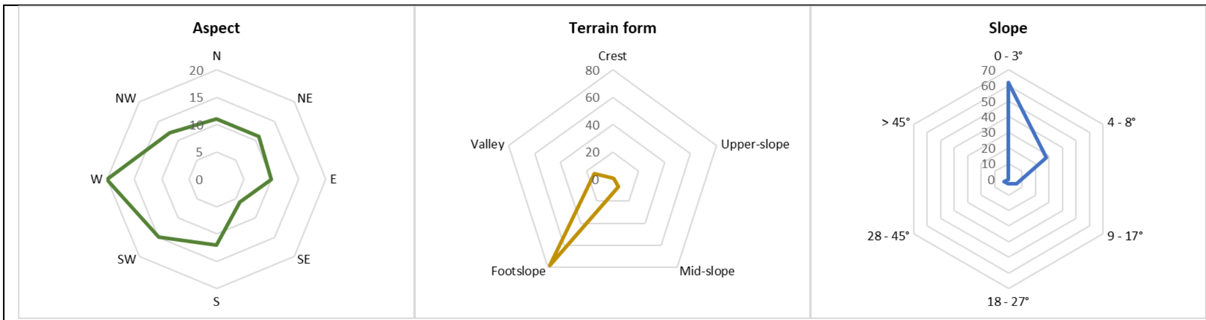
No IUCN Red List species or endemic species were recorded at sampling plots across the Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd) habitat type.

5.2.5. Evergreen and semi-evergreen bushland and thicket (Be)

5.2.5.1. Location and environmental features

Sampling plots within the Evergreen and semi-evergreen bushland and thicket (Be) habitat type occurred at an altitude ranging from 1803 to 2202 m asl (mean 1950 m asl). The aspect was predominantly west and south-west; but also varied between north, north-west, north-east, east, south-east and south. The dominant terrain form were foot-slopes, however mid-slopes and upper-slopes also featured with a generally flat gradient (0 - 3°), while other areas experienced gradual (4 - 8°) to moderate (9 - 17°) gradients (Table 8). The mean percentage cover of rock, sand and grit was 7.5%, which was comprised up of pebbles (1.1%), stones (1.6%), rocks (2.8%), boulders (1.8%) and exposed bare rock (0.3%).

Table 8: Summary of the dominant environmental features of the Evergreen and semi-evergreen bushland and thicket (Be) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)	**Overall rock, sand and grit**	**7.5**
	Pebbles	1.1
	Stones	1.6
	Rocks	2.8
	Boulders	1.8
	Exposed bare rock	0.3

5.2.5.2. Floristic composition

The following species had an occurrence of ≥ 40% across all sample plots in the Evergreen and semi-evergreen bushland and thicket (Be) habitat type: *Sida tenuicarpa*, *Hypoestes forskaolii*, *Psiadia punctulata*, *Solanum campylacanthum*, *Conyza bonariensis*, *Cynodon dactylon*, *Ocimum gratissimum*, *Vachellia xanthophloea*, *Cynodon nlemfuensis*, *Tarchonanthus camphoratus*, *Fuerstia africana*, *Gymnosporia heterophylla* and *Themeda triandra*.

5.2.5.3. Vegetation structure

The dominant class for trees were the regeneration level trees, which had a mean height of 2.0 m (mean cover percentage = 65.0%) and the sub-dominant class were canopy trees, which had a mean height of 9.5 m (mean cover percentage = 42.4%) (Appendix II, Table A). The dominant class for shrubs were the high shrubs, which had a mean height of 4.1 m (mean cover percentage = 50.7%) and the sub-dominant class were very high shrubs, which had a mean height of 6.0 m (mean cover percentage = 30.0%) (Appendix II, Table B). The dominant class of grasses were the low-level grasses, which had a mean height of 0.2 m (mean cover percentage = 58.2%) and the sub-dominant class were medium grasses, which had a mean height of 1.0 m (mean cover percentage = 47.1%) (Appendix II, Table C).

5.2.5.4. Plant diversity

Plant diversity in the Evergreen and semi-evergreen bushland and thicket (Be) was moderate-high. The mean number of species per sample plot for the 102 plots surveyed was 32 species with a range from 8 to 62 species.

5.2.5.5. IUCN Red List species and endemic species

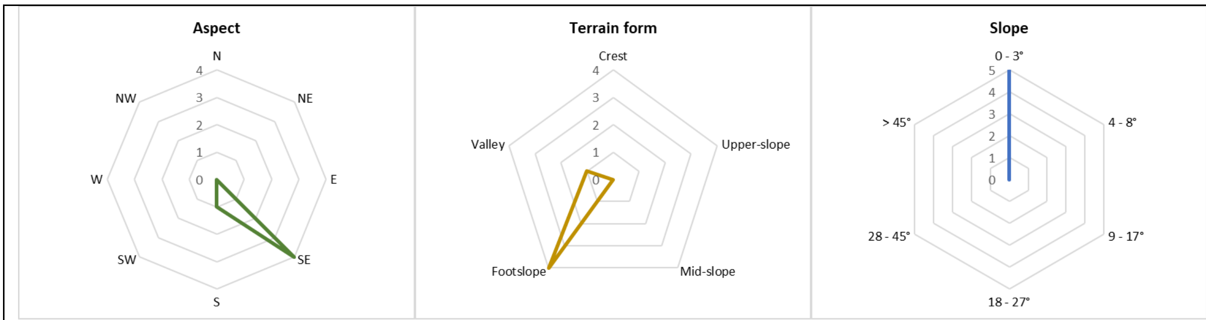
Ansellia africana (Vulnerable) was recorded across 2% of the sampling plots in the Evergreen and semi-evergreen bushland and thicket (Be) habitat type. No endemic species were recorded.

5.2.6. Halophytic vegetation (Z)

5.2.6.1. Location and environmental features

Sampling plots within the Halophytic vegetation (Z) habitat type occurred at an altitude ranging from 1786 to 1795 m asl (mean 1791 m asl). The aspect was predominantly south-east on foot-slope and valley bottom terrain, with flat (0 - 3°) gradients (Table 9). The mean percentage cover of rock, sand and grit (pebbles, stones, rocks, boulders and exposed bare rock) was 0.0%.

Table 9: Summary of the dominant environmental features of the Halophytic vegetation (Z) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)	**Overall rock, sand and grit**	**0.0**
	Pebbles	0.0
	Stones	0.0
	Rocks	0.0
	Boulders	0.0
	Exposed bare rock	0.0

5.2.6.2. Floristic composition

The following species had an occurrence of ≥ 40% across all sample plots in the Halophytic vegetation (Z) habitat type: *Chloris gayana, Craterostigma pumilum, Cycnium tubulosum, Sida tenuicarpa, Vachellia xanthophloea, Cynodon nlemfuensis, Hypoestes forskaolii, Kalanchoe densiflora, Scutia myrtina, Senecio hadiensis, Senecio moorei, Sporobolus agrostoides, Achyranthes aspera, Capparis tomentosa, Chenopodium album, Chenopodium* cf*. opulifolium, Commelina benghalensis, Cordia monoica, Cynodon dactylon, Gymnosporia heterophylla, Harpachne schimperi, Oldenlandia corymbosa, Oldenlandia monanthos, Opuntia ficus-indica, Pavetta sp.* and *Tagetes minuta.*

5.2.6.3. Vegetation structure

The dominant class for trees were the canopy trees, which had a mean height of 16.0 m and a mean percentage cover of 72.5% (Appendix II, Table A). The dominant class for shrubs were the medium shrubs class, which had a mean height of 3.0 m and a mean percentage cover of 10.0% (Appendix II, Table B). The dominant class of grasses were the low-level grasses, which had a mean height of 0.2 m (mean cover percentage = 75.8%) and the sub-dominant class were high grasses, which had a mean height of 1.4 m (mean cover percentage = 60.0%) (Appendix II, Table C).

5.2.6.4. Plant diversity

Plant diversity in the Halophytic vegetation (Z) was moderate. The mean number of species per sample plot for the five plots surveyed was 21 species with a range from 15 to 25 species.

5.2.6.5. IUCN Red List species and endemic species

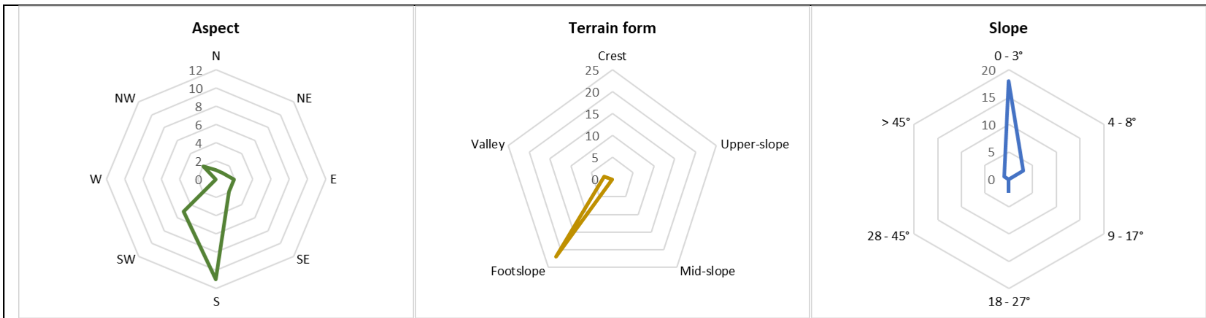
No IUCN Red List species or endemic species were recorded at sampling plots across the Halophytic vegetation (Z) habitat type.

5.2.7. <u>Riverine wooded vegetation (R)</u>

5.2.7.1. Location and environmental features

Sampling plots within the Riverine wooded vegetation (R) habitat type occurred at an altitude ranging from 1795 to 1977 m asl (mean 1880 m asl). The aspect was predominantly south and south-west on foot-slope terrain with flat (0 - 3°) gradients (Table 10). Stones had a mean percentage cover of 0.2%, which contributed wholly to the 0.2% mean percentage cover of rock, sand and grit.

Table 10: Summary of the dominant environmental features of the Riverine wooded vegetation (R) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)		
	Overall rock, sand and grit	**0.2**
	Pebbles	0.0
	Stones	0.2
	Rocks	0.0
	Boulders	0.0
	Exposed bare rock	0.0

5.2.7.2. Floristic composition

The following species had an occurrence of ≥ 40% across all sample plots in the Riverine wooded vegetation (R) habitat type: *Vachellia xanthophloea, Achyranthes aspera, Hypoestes forskaolii, Cynodon nlemfuensis, Sida* *tenuicarpa, Gymnosporia heterophylla, Phytolacca dodecandra, Conyza bonariensis, Senecio hadiensis, Commelina benghalensis, Cynanchum altiscandens, Setaria verticillata, Solanum campylacanthum* and *Tagetes minuta*.

5.2.7.3. Vegetation structure

The dominant class for trees were the canopy trees, which had a mean height of 14.1 m (mean cover percentage = 48.6%) and the sub-dominant class were mid-canopy trees, which had a mean height of 7.6 m (mean cover percentage = 33.8%) (Appendix II, Table A). The dominant class for shrubs were the high shrubs, which had a mean height of 4.3 m (mean cover percentage = 25.0%) and the sub-dominant class were medium shrubs, which had a mean height of 2.5 m (mean cover percentage = 12.8%) (Appendix II, Table B). The dominant class of grasses were the low-level grasses, which had a mean height of 0.2 m (mean cover percentage = 63.1%) and the sub-dominant class were high grasses, which had a mean height of 1.3 m (mean cover percentage = 46.4%) (Appendix II, Table C).

5.2.7.4. Plant diversity

Plant diversity in the Riverine wooded vegetation (R) was moderate-high. The mean number of species per sample plot for the 24 plots surveyed was 28 species with a range from 16 to 53 species.

5.2.7.5. IUCN Red List species and endemic species

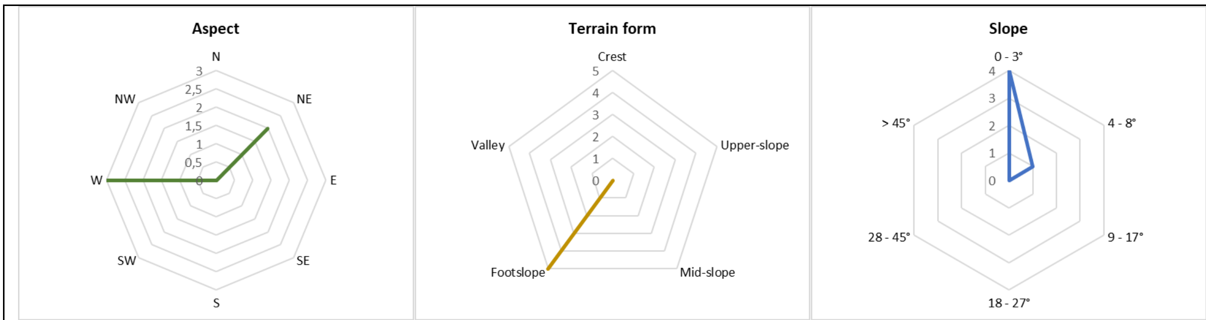
No IUCN Red List species or endemic species were recorded at sampling plots across the Riverine wooded vegetation (R) habitat type.

5.2.8. Upland *Acacia* wooded grassland (We)

5.2.8.1. Location and environmental features

Sampling plots within the Upland *Acacia* wooded grassland (We) habitat type occurred at an altitude ranging from 1915 to 1973 m asl (mean 1943 m asl). The aspect was predominantly west and north-east on foot-slope terrain, with flat (0 - 3°) to gradual (4 - 8°) gradients (Table 11). The mean percentage cover of rock, sand and grit was 9.0%. The mean percentage cover of pebbles, stones, rocks, boulders and exposed bare rock was 0%, 1.0%, 6.0%, 2.0% and 0.0%, respectively.

Table 11: Summary of the dominant environmental features of the Upland *Acacia* wooded grassland (We) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)	**Overall rock, sand and grit**	**9.0**
	Pebbles	0.0
	Stones	1.0
	Rocks	6.0
	Boulders	2.0
	Exposed bare rock	0.0

5.2.8.2. Floristic composition
The following species had an occurrence of ≥ 40% across all sample plots in the Upland *Acacia* wooded grassland (We) habitat type: *Chloris gayana, Conyza bonariensis, Cynodon dactylon, Laggera alata, Sporobolus pyramidalis, Ageratum conyzoides, Bidens pilosa, Chloris pycnothrix, Indigofera hochstetteri, Lantana camara, Schkuhria pinnata, Solanum campylacanthum, Tagetes minuta, Aristida congesta* subsp. *barbicollis, Asparagus racemosus, Crotalaria incana, Cycnium tubulosum, Indigofera bogdanii, Lantana trifolia, Leucas grandis, Ocimum gratissimum, Oxalis corniculata, Richardia brasiliensis, Sida tenuicarpa, Themeda triandra, Trifolium rueppelianum, Vachellia xanthophloea, Verbena bonariensis* and *Vernonia glabra.*

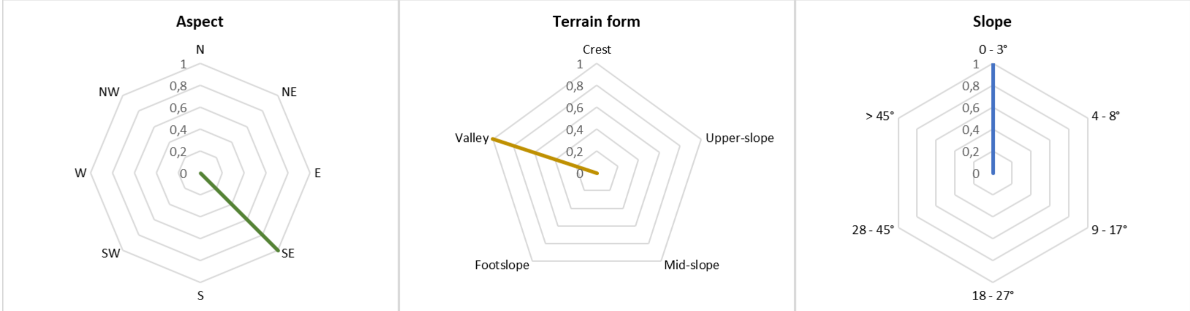
5.2.8.3. Vegetation structure
The dominant class for trees were the canopy trees, which had a mean height of 12.0 m and a mean percentage cover of 20.0% (Appendix II, Table A). The dominant class for shrubs were the medium shrubs class, which had a mean height of 2.7 m and a mean percentage cover of 8.3% (Appendix II, Table B). The dominant class of grasses were the low-level grasses, which had a mean height of 0.4 m (mean cover percentage = 78.0%) and the sub-dominant class were medium grasses, which had a mean height of 0.8 m (mean cover percentage = 51.7%) (Appendix II, Table C).

5.2.8.4. Plant diversity
Plant diversity in the Upland *Acacia* wooded grassland (We) was moderate. The mean number of species per sample plot for the five plots surveyed was 27 species with a range from 20 to 38 species.

5.2.8.5. IUCN Red List species and endemic species
No IUCN Red List species or endemic species were recorded at sampling plots across the Upland *Acacia* wooded grassland (We) habitat type.

5.2.9. Freshwater swamp (X)
5.2.9.1. Location and environmental features
One sampling plot occurred within the Freshwater swamp (X) habitat type. The altitude was 1782 m asl with a south-easterly aspect, occurring in a valley bottom with a flat (0 - 3°) gradient (Table 12). The mean percentage cover of rock, sand and grit (pebbles, stones, rocks, boulders and exposed bare rock) was 0.0%.

Table 12: Summary of the dominant environmental features of the Freshwater swamp (X) habitat type along the Kenya Summit Highway study area, Kenya



Mean cover (%)		
	Overall rock, sand and grit	**0.0**
	Pebbles	0.0
	Stones	0.0
	Rocks	0.0
	Boulders	0.0
	Exposed bare rock	0.0

5.2.9.2. Floristic composition

The following species had an occurrence of ≥ 40% across all sample plots in the Freshwater swamp (X) habitat type (Note: there was only one sampling plot in this habitat type, therefore the species recorded have a 100% occurrence): *Achyranthes aspera, Chenopodium opulifolium, Chloris virgata, Conyza bonariensis, Cordia monoica, Cynanchum altiscandens, Cynodon dactylon, Grewia similus, Gymnosporia heterophylla, Justicia anagalloides, Kalanchoe densiflora, Opuntia ficus-indica, Pappea capensis, Pavonia patens, Searsia natalensis, Senecio hadiensis, Senecio moorei, Vachellia xanthophloea* and *Warburgia ugandensis.*

5.2.9.3. Vegetation structure

The dominant class for trees were the canopy trees, which had a mean height of 14.0 m and a mean percentage cover of 40.0% (Appendix II, Table A). The dominant class for shrubs were the medium shrubs class, which had a mean height of 3.0 m and a mean percentage cover of 10.0% (Appendix II, Table B). The dominant class of grasses were the low-level grasses, which had a mean height of 0.2 m (mean cover percentage = 92.0%) (Appendix II, Table C).

5.2.9.4. Plant diversity

Plant diversity in the Freshwater swamp (X) was moderate. The total number of species per sample plot for the one plot surveyed was 19 species.

5.2.9.5. IUCN Red List species and endemic species

No IUCN Red List species or endemic species were recorded at sampling plots across the Freshwater swamp (X) habitat type.

5.3. Assessment of habitat degradation, fragmentation and quality

5.3.1. Habitat degradation

The mean values for the assessment highlight a moderate score of 2.9 (Appendix III, Table A), which highlights that despite obvious degradation evidence, the land area investigated retains the potential to rapidly bounce back naturally (score > 2.0) should it be left unperturbed for a short period of time. However, on a habitat level, the Afromontane rain forest (Fa) has lost this potential and may not be able to regenerate naturally. The Afromontane bamboo (B) habitat and the Upland *Acacia* wooded grassland (We) are the next two most degraded habitat types, with the Freshwater swamp (X) (Water bodies) and the Halophytic vegetation (Z) habitat types are noted as least degraded over the Local Assessment Area.

5.3.2. Habitat fragmentation

It is clear that the Local Assessment Area has reached an advanced stage of fragmentation with 41% of sites visited falling within that class with a mean score of 2.9 (Appendix III, Table B), highlighting that a transition to the next stage in the sequence has already started. The latter is evident by the fact that 25% of sites highlighted an intermediate level of attrition whereby natural habitat fragments had lost their natural outlook and were eroded through edge effect. Only 4% of sites visited were at an attrition stage, while 30% of sites visited were classified at the perforation stage. Overall, at least two thirds of the sites visited highlighted that fragmentation had occurred and was a prevalent matter.

5.3.3. Habitat quality

It is apparent that at least one third of the Local Assessment Area is already within the realm of modified conditions and no longer retains the basic structure necessary for natural conditions (Appendix III, Table C). For the remainder of the Regional Assessment Area, whilst it technically falls within the natural condition realm, most of it has already suffered light to medium modification influences and this is noted as most likely evolving towards a heavily modified stage. The most natural habitat type encountered in terms of botanical investigations was the Freshwater swamp (X) [Water bodies (w)], followed by Halophytic vegetation (Z) usually surrounding the water bodies. Riverine wooded vegetation (R) was generally noted as having suffered degradation and light to medium modification. Evergreen and semi-evergreen bushland and thicket (Be) were generally under the meso modification stage, while the Afromontane undifferentiated forest (Fb) habitat was generally heavily modified, although not as profoundly as the remainder of habitat types. The Afromontane bamboo (B), Afromontane rain forest (Fa), Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd) and Upland *Acacia* wooded grasslands (We) were deemed to be heavily modified with >50% of sampled sites within these habitat types falling within that stage.

6. DISCUSSION

6.1. Species accumulation curves and sampling sufficiency

The species accumulation curve for the combined dry and wet season surveys (containing 181 sampling plots) showed that sampling sufficiency was just reached at approximately 180 sampling plots, which is the point where the tangent meets the curve i.e., the point where for every one new sample plot surveyed, one new species is recorded. Using the fitted curve equation, it appears that 212 additional plots would have been required to add 100 species, which represents more than double the effort expanded. The work conducted, as a combined item between November, February and April is therefore considered as satisfactory to represent the species richness along the road alignment diversity of habitats.

The seasonal species accumulation curves highlight a "step" in the pattern towards the end of each of the two survey seasons after approximately 70 sites have been sampled. As the sampling work proceeded from the Mau Summit end of the Local Assessment Area to the Nairobi direction, these steps in the curve highlight the switch to the highlands between Naivasha and Rironi, where different habitat types are encountered, and new species are added suddenly.

The pattern of the curves observed is typical of the linear nature of the Local Assessment Area, which is traversing numerous broad habitat types in sequence, each with their own assemblage of species. The number of species encountered may also be influenced by the season, as can be noted between the February and the April curves, whereby the February curve shows a step followed by a plateau between 80 and 90 sites whereas the April curve highlights a climbing pattern that has not yet reached a plateau. As can be noted on the curve patterns, the sections of road from Mau summit to Naivasha appear to have been sampled satisfactorily and have "merged" in the curve, while the section from Naivasha to Rironi appears likely to necessitate more surveys before this can be fully confirmed. The latter aspect is, however, "dampened" considerably in the overall view.

6.2. Species of conservation concern and endemism

Lagarosiphon hydrilloides is considered native to Kenya and generally found in still or slow-flowing freshwater at altitudes of 1650 to 3500 m asl. Morphologically this species is characterised by spirally arranged, recurved leaves in whorls near the base of the stem. The leaves contain two narrow bands of fibres on either side of the midrib with 2 to 4 bands of submarginal fibres (Agnew, 2013). Leaf margins are denticulate. Although many suitable habitats where sampled, this species was not encountered in the survey area during the survey period but may be present based on plant herbarium collection locations.

Another species of concern, sampled from Kenya and Uganda only, is *Ethulia schefflera*, known to occur on swampy sites along streams, and in marshy grassland with black cotton soil. However, literature only indicate sample locations from Kedong, south of Mount Longonot National Park in Naivasha district. The species is described as a 90 to 200 cm tall herb or shrub with unpleasant smelling leaves and blue-mauve, purple or violet inflorescence (Agnew, 2013). This species was not recorded in the Local Assessment Area during the survey periods.

Other tree species (Beentje, 1994) of concern (based on IUCN classification criteria) with confirmed occurrence are *Ocotea kenyensis* (VU), *Prunus africana* (VU), found in the Afromontane bamboo and Afromontane undifferentiated forest vegetation units. The orchid (Agnew, 2013), *Ansellia africana* (VU) was present in the Evergreen and semi-evergreen bushland and thicket vegetation unit.

The Kenyan endemic, *Kleinia gregorii* was also confirmed as present in the Evergreen and semi-evergreen bushland and thicket vegetation unit.

6.3. Synthesis

The most unique habitats are found along drainage lines, river systems, wetlands and rocky ridges throughout the Nairobi-Nakuru-Mau Summit Highway Project Local Assessment Area. Each of these areas contain unique biodiversity elements that contribute to optimizing ecosystem functionality and providing various ecosystem services to wildlife, livestock and humans.

Areas which stand out in these respects include the rocky ridges along the highway around Lake Elmenteita in the Evergreen and semi-evergreen bushland and thicket (Be) habitat type, as well as the calcareous soils along drainage lines of the Be habitat type (Figure 8). These areas accommodate species such as *Aloe* spp., *Euphorbia* spp., *Orbea* spp and various orchid species such as *Ansellia africana* and *Eulophia speciosa*.

a) b)

Figure 8: a) Ridges of the Evergreen and semi-evergreen bushland and thicket (Be) habitat type, south-east of Lake Elmenteita [sampling plot 428] and b) unique vegetation occurring on calcareous soils along drainage lines of the Be habitat type [sampling plot 323].

Other unique areas include the natural patches of indigenous Afromontane Forest in the north-western extent of the Local Assessment Area near Molo (Koibatek Forest) as well as the escarpment forest zone in the south-eastern extent of the Local Assessment Area along the existing Kamandura-Mai Mahiu-Narok Road (proposed A8 South Highway).

The heavily disturbed and transformed areas contain a high diversity and abundance of alien/exotic plant species. Numerous "naturalized" invasives were recorded in these areas and the dominant alien/exotic species recorded were: *Acacia mearnsii, Acacia melanoxylon, Agave americana, Agave sisalana, Austrocylindropuntia subulata, Azolla filiculoides, Bougainvillea spectabilis, Carica papaya, Casuarina equisetifolia, Cedar spp., Cereus jamacaru, Chenopodium album, Cirsium vulgare, Datura stramonium, Eichhornia crassipes, Ensete ventricosum, Eucalyptus spp., Grevillea robusta, Guilleminia densa, Jacaranda mimosifolia, Lantana camara, Lemna minor, Musa* × *paradisiaca, Nerium oleander, Opuntia ficus-indica, Pinus spp., Richardia brasiliensis, Ricinus communis, Schinus molle, Tagetes minuta, Yucca spp.* and *Zea mays*.

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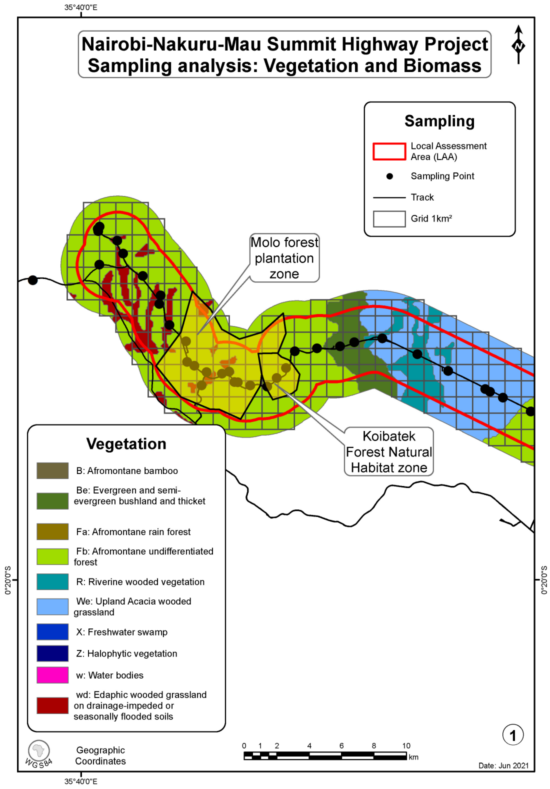
8. APPENDIX I – FINE SCALE REPRESENTATION OF VECEA HABITAT TYPES



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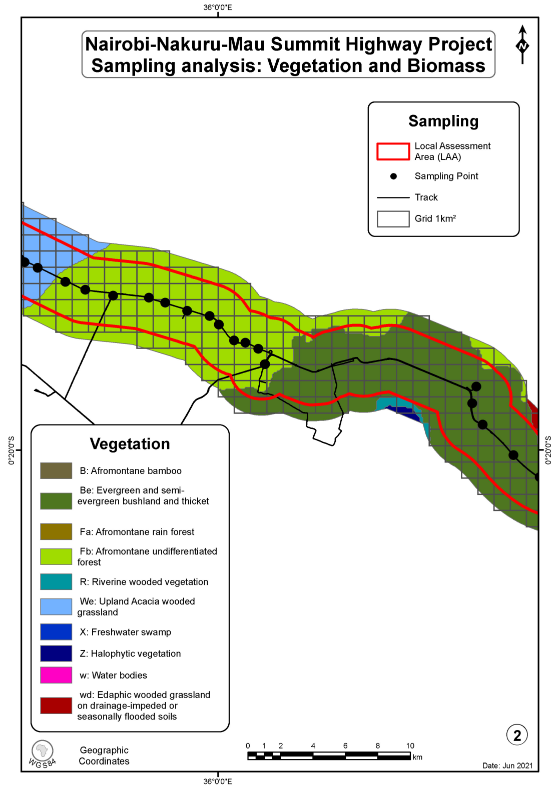

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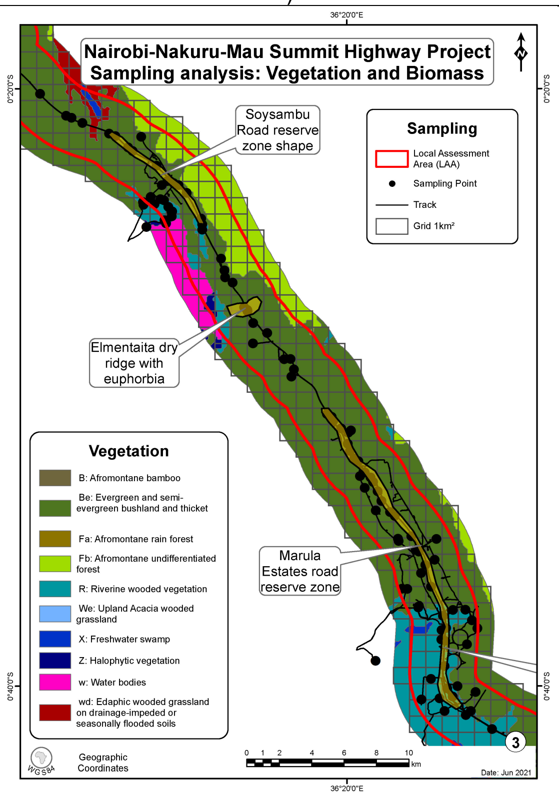

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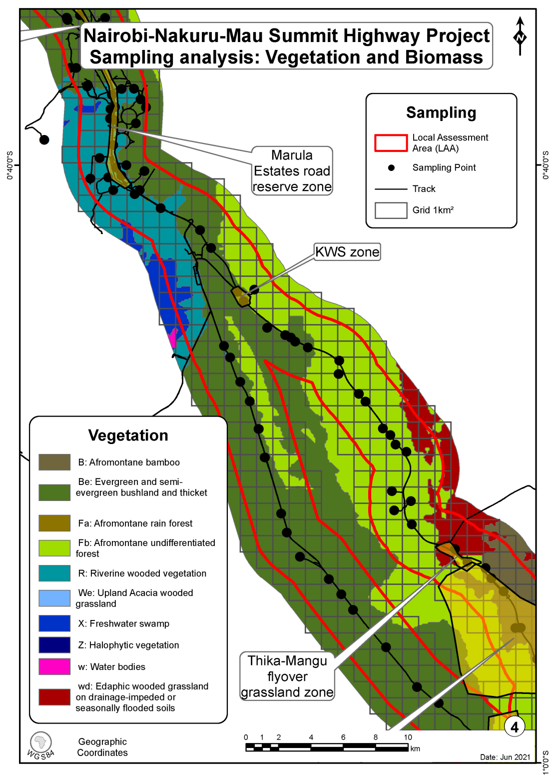

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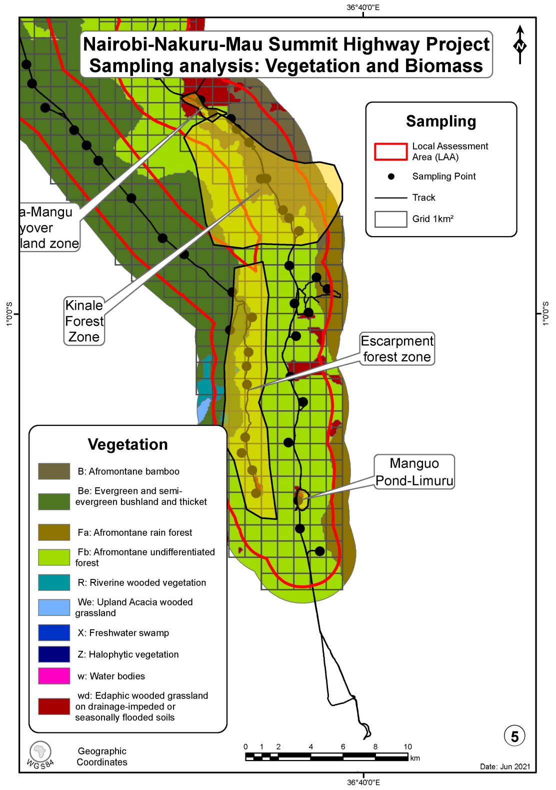

e)

Figure A: VECEA habitat types throughout sections of the Local Assessment Area from the north-western extent through the south-eastern extent of the proposed Nairobi-Nakuru-Mau Summit Highway Project (a – e).

a) Afromontane bamboo (B) habitat type.

b) Afromontane rain forest (Fa) habitat type.

c) Afromontane undifferentiated forest (Fb) habitat type

d) Edaphic wooded grassland on drainage-impeded or seasonally flooded soils (wd)

e) Evergreen and semi-evergreen bushland and thicket (Be)

f) Halophytic vegetation (Z)

g) Riverine wooded vegetation (R)

h) Upland Acacia wooded grassland (We)

i) Freshwater swamp (X)

Figure B: Photos of the VECEA habitat types occurring throughout the Regional Assessment Area.

9. APPENDIX II – GENERAL VEGETATION STRUCTURE FEATURES

Table A: Mean height and percentage cover of trees for the various classes of vegetation structure across the VECEA habitat types

Habitat types (VECEA)	Mean height of trees (in m) for the Emergent trees class	Mean height of trees (in m) for the Canopy trees class	Mean height of trees (in m) for the Mid Canopy trees class	Mean height of trees (in m) for the Regeneration level trees class	Mean cover of trees (%) for the Emergent trees class	Mean cover of trees (%) for the Canopy trees class	Mean cover of trees (%) for the Mid Canopy trees class	Mean cover of trees (%) for the Regeneration level trees class
Afromontane bamboo		17.0				90.3		
Afromontane rain forest		16.0				90.0		
Afromontane undifferentiated forest	22.0	12.7	9.1	5.7	5.0	42.3	33.1	30.0
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils		20.0				40.0		
Evergreen and semi-evergreen bushland and thicket		9.5	8.7	2.0		42.4	41.9	65.0
Halophytic vegetation		16.0				72.5		
Riverine wooded vegetation		14.1	7.6			48.6	33.8	
Upland Acacia wooded grassland		12.0				20.0		
Water bodies		14.0				40.0		
Grand Total	22.0	11.9	8.5	4.5	5.0	45.8	36.0	41.7

Table B: Mean height and percentage cover of shrubs for the various classes of vegetation structure across the VECEA habitat types

Habitat types (VECEA)	Mean height of shrubs (in m) for the Very High shrubs class	Mean height of shrubs (in m) for the High shrubs class	Mean height of shrubs (in m) for the Medium shrubs class	Mean height of shrubs (in m) for the Low level shrubs class	Mean cover of shrubs (%) for the Very High shrubs class	Mean cover of shrubs (%) for the High shrubs class	Mean cover of shrubs (%) for the Medium shrubs class	Mean cover of shrubs (%) for the Low level shrubs class
Afromontane bamboo		4.0				60.0		
Afromontane rain forest			3.0				40.0	
Afromontane undifferentiated forest	6.0	4.6	2.7	1.8	41.7	40.6	22.0	25.5
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils								
Evergreen and semi-evergreen bushland and thicket	6.0	4.1	2.6	1.4	30.0	50.7	22.9	14.3
Halophytic vegetation			3.0				10.0	
Riverine wooded vegetation		4.3	2.5			25.0	12.8	
Upland Acacia wooded grassland			2.7				8.3	
Water bodies			3.0				10.0	
Grand Total	6.0	4.4	2.6	1.5	37.0	42.9	20.2	18.0

Table C: Mean height and percentage cover of grasses for the various classes of vegetation structure across the VECEA habitat types

Habitat types (VECEA)	Mean height of Grasses (in m) for the Very High Grasses class	Mean height of Grasses (in m) for the High Grasses class	Mean height of Grasses (in m) for the Medium Grasses class	Mean height of Grasses (in m) for the Low level Grasses class	Mean cover of Grasses (%) for the Very High Grasses class	Mean cover of Grasses (%) for the High Grasses class	Mean cover of Grasses (%) for the Medium Grasses class	Mean cover of Grasses (%) for the Low level Grasses class
Afromontane bamboo	1.6		0.8	0.2	60.0		10.0	57.0
Afromontane rain forest	1.6		0.8	0.2	35.0		5.0	71.5
Afromontane undifferentiated forest	1.7	1.3	1.0	0.2	47.3	43.1	36.0	53.1
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils			0.9	0.2			35.0	65.0
Evergreen and semi-evergreen bushland and thicket	1.7	1.3	1.0	0.2	41.8	46.7	47.1	58.2
Halophytic vegetation		1.4	1.0	0.2		60.0	17.5	75.8
Riverine wooded vegetation	1.6	1.3	0.8	0.2	25.0	46.4	44.5	63.1
Upland Acacia wooded grassland	1.6	1.4	0.8	0.4	12.5	20.0	51.7	78.0
Water bodies				0.2				92.0
Grand Total	1.6	1.3	0.9	0.2	41.1	45.7	41.1	59.1

10. APPENDIX III – HABITAT DEGRADATION, FRAGMENTATION AND QUALITY

Table A: Assessment of habitat degradation of the study area

Habitat types (VECEA)	Habitat fragment access (5 = within biological limits, 1 = outside biological limits)	Habitat fragment size (5 = non fragmented, 1 = remnant)	Seed dispersers (5 = large & numerous, 1 = absent)	Seed size dispersed (5 = large, 1 = minute)	Fire risk level (5 = low, 1 = high)	Live tree stumps (5 = none to very low, 1 = ubiquitous)	Dead wood abundance (5 = high load, 1 = scarce)	Mean (5 = good condition, 1 = poor condition)
Afromontane bamboo	1.8	2.6	1.2	1.2	2.8	3.0	2.6	2.3
Afromontane rain forest	1.0	1.0	1.0	0.5	3.5	1.0	1.0	1.5
Afromontane undifferentiated forest	2.2	2.2	2.7	2.4	3.7	2.8	2.3	2.8
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	2.3	2.0	3.0	2.3	5.0	3.7	3.7	3.2
Evergreen and semi-evergreen bushland and thicket	2.8	2.9	2.8	2.5	4.0	2.9	2.1	3.0
Halophytic vegetation	3.8	4.2	3.4	3.2	5.0	4.8	4.4	3.9
Riverine wooded vegetation	3.5	2.8	2.8	2.6	4.3	4.0	2.3	3.2
Upland Acacia wooded grassland	1.4	2.2	2.2	2.2	3.4	3.2	3.0	2.5
Water bodies	5.0	5.0	4.0	4.0	5.0	5.0	5.0	4.5
Grand Total	2.6	2.7	2.7	2.5	3.9	3.0	2.3	2.9

Table B: Assessment of habitat fragmentation of the study area

Habitat types (VECEA)	Dissection score - linear cuts through the habitat as access roads are created (1 = low, 5 = high)	Dissection - % of sites with Dissection status per habitat type	Perforation score - holes develop in the habitat where humans settle (1 = low, 5 = high)	Perforation - % of sites with Perforation status per habitat type	Fragmentation score - settlements zones become greater in extent than habitat islands (1 = low, 5 = high)	Fragmentation - % of sites with Fragmentation status per habitat type	Attrition score - isolated habitat remnants are gradually eroded by edge effect (5 = low, 1 = high)	Attrition - % of sites with Attrition status per habitat type
Afromontane bamboo					3.5	80%	1.0	20%
Afromontane rain forest					2.5	100%		
Afromontane undifferentiated forest	2.5	4%	2.8	27%	2.9	44%	2.2	25%
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils					3.3	100%		
Evergreen and semi-evergreen bushland and thicket	3.3	5%	2.2	34%	2.8	40%	2.7	21%
Halophytic vegetation	5.0	20%	2.0	40%			4.0	40%
Riverine wooded vegetation			2.7	29%	3.2	24%	3.1	48%
Upland Acacia wooded grassland			3.5	40%	2.0	40%	3.0	20%
Water bodies			1.0	100%				
Grand Total	3.3	4%	2.4	30%	2.9	41%	2.6	25%

Table C: Assessment of habitat quality of the study area

Habitat condition analysis	Natural conditions								Modified conditions			
Habitat types (VECEA)	Mean of Site quality Pristine / Natural (1-5)	% of Site quality Pristine / Natural (1-5)	Mean of site quality "Degraded" with structure retained (5 = very low degradation, 1 = very high degradation)	% of Site quality Degraded (1-5)	Lightly Modified (minimal loss of structure, 5 = low, 1 = significant)	% of Site quality Lightly modified (1-5)	Meso Modified (loss of structure and functionality, 5 = low, 1 = significant))	% of Site quality Medium modified 1-5)	Heavily Modified (basic structure elements left, low remaining functionality, 5 = low, 1 = significant)	% of Site quality Heavy modified (1-5)	Transformed (original structure and functionality is lost, 5 = light transformation, 1 = build up)	% of Site quality Transformed (1-5)
Afromontane bamboo					4.0	20%			4.3	80%		
Afromontane rain forest									4.0	100%		
Afromontane undifferentiated forest	2.5	4%	3.2	9%	3.2	9%	3.4	28%	4.5	49%		
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils			2.0	33%					4.5	67%		
Evergreen and semi-evergreen bushland and thicket	3.6	6%	3.4	13%	3.4	23%	4.2	30%	4.2	30%		
Halophytic vegetation	3.5	40%	4.0	20%			4.0	40%				
Riverine wooded vegetation	2.6	21%	3.5	33%	3.3	13%	4.0	17%	4.3	17%		
Upland Acacia wooded grassland							4.0	40%	4.0	60%		
Water bodies	4.0	100%										
Grand Total	3.1	8%	3.3	14%	3.3	16%	3.9	26%	4.3	36%		

Natural conditions: **If human influence were to be removed, natural conditions may be restored naturally through the presence of naturally occurring species, short to medium term timeframes may be possible for return to natural conditions**

Pristine / Natural : Habitat type contains the original and expected naturally occuring species, pristine sites have no sign of human influence while naturalness is defined by the number of human use signs

Degraded : Original species assemblage generally retained, some alien species may occur, but habitat structure modification can be noticed, although it is not pervasive

Lightly modified : Structure has been modified and non natural species assemblage exceeds > 10% of expected species number

Meso modified : Structure has been modified, extensively at times, non natural species assemblage exceeds > 20% of expected species number

Modified conditions : **If human influence were to be removed, natural conditions could not be restored naturally, active restoration would be required to ensure species can re-establish, medium to long term timeframes required**

Heavily modified : Structure has been extensively modified with original species retained as remnants, non natural species assemblage typically exceed > 30% of expected species number

Transformed: Structure has been lost and replaced by a man made assemblage, naturally occuring species retained as remnants, non natural species assemblages may exceed > 40% of expected species number

APPENDIX

6-15 *BIODIVERSITY BASELINE INVESTIGATION – VEGETATION: WOODY BIOMASS, CARBON AND WOODY POPULATIONS CONDITION*

Nairobi-Nakuru-Mau Summit Highway Project
Expansion & Upgrade
Biodiversity baseline studies for the ESIA
Republic of Kenya

BIODIVERSITY BASELINE INVESTIGATION
Vegetation: Woody biomass, carbon and woody populations condition
FINAL REPORT

Compiled by
Phoebe Mottram, *CandSciNat*
Jerome Gaugris, *PriScNat*
Ben Orban, *PriSciNat*

With support from
Graeme Wolfaard, PriSciNat
Itambo Malombe, Expert

July 2021

Quality Control	Reviewer	Request
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FINAL version	Phoebe Mottram, *Cand.Sci.Nat* Jerome Gaugris, *Pri.Sci.Nat.*	

Table of Contents

A BASELINE SURVEY OF THE WOODY PLANT SPECIES POPULATIONS AND ASSOCIATED CARBON / BIOMASS CONTAINED IN THE WOODY VEGETATION IN THE ENVIRONS OF NAIROBI TO MAU SUMMIT STUDY AREA, CENTRAL KENYA

1 CONTEXT

WSP Canada has been commissioned by Rift Valley Highway Limited (RVHL) to complete the Environmental and Social Impact Assessment (ESIA) for the Rironi to Mau Summit Highway Expansion and Upgrade Project. The ESIA is undertaken in order to anticipate and identify adverse environmental and social risks and develop robust mitigation measures through the application of mitigation hierarchy. As part of the WSP Canada consortium in the proposal made to RVHL, Flora Fauna & Man Ecological Services Ltd (FFMES) has been tasked to undertake the biodiversity surveys along the proposed road alignment. A first round of work, covering the dry season was undertaken in February 2021, from 17 to 26 February (10 days of field work). Another round of work, covering the wet season, was undertaken from 13 to 25 April 2021 (12 days of field work). The work was undertaken by a multidisciplinary team of experts spanning the following disciplines:

- Vegetation, including woody biomass;
- Mammals (including small terrestrial mammals);
- Avifauna;
- Herpetofauna (Reptiles & Amphibians);
- Freshwater ecology.

The present document provides an outline of the work undertaken with respect to the following disciplines:

- Vegetation
  - Section 2 of 2: Report on the woody biomass aspects

This work was undertaken by the following team members:

- Team leader:	Ben Orban
o Degrees	MSc Wildlife Management
o Professional accreditation	SACNASP Professional Scientist in Ecological & Botanical Science
o Number of years of experience	27
o Number of publications in the field if relevant	16
o Prior experience in the country or region:	East Africa (Ethiopia, Uganda, Tanzania)
- Assistant 1:	Phoebe Mottram
o Degrees:	M.Sc. Conservation Biology, B.Sc. (hons) Geography
o Professional accreditation:	SACNASP Candidate Natural Scientist in Environmental Science
o Number of years of experience:	3
o Number of scientific publications in the field:	1
o Prior experience in the country or region:	NA
- Assistant 2:	Jerome Gaugris
o Degrees:	PhD and MSc in Wildlife Management
o Professional accreditation:	SACNASP Professional Scientist in Ecological Science
o Number of years of experience:	21
o Number of publications in the field:	26
o Prior experience in the country or region	East Africa (Burundi, Rwanda, Uganda, Ethiopia, Tanzania and Kenya)

2 INTRODUCTION

Globally carbon is found in five reservoirs, i.e., the oceanic, fossil fuel, pedologic (soil), atmospheric and the biotic reservoirs (Lal, 2008). The latter is the smallest of all the carbon reservoirs, but it is heavily impacted by human activities. Deforestation is currently the third largest source of carbon emissions and accounts for approximately 18% of global carbon emissions (Keith *et al*. 2009). As a consequence of the worldwide interest in carbon sequestration for REDD+ (Reducing emissions from deforestation and degradation, including forest conservation, sustainable management of forests, and enhancement of forest carbon stocks), many studies in recent years have focussed on carbon related assessments of vegetation to estimate the potential of such vegetation to capture carbon and contribute towards mitigating climate change. A host of studies have also concentrated on estimating the carbon content of African forests through satellite imagery analysis to assess the potential financial gains under the REDD+ mechanism (Ediriweera *et al*. 2013; Ernst *et al*. 2013). However, most of these studies have limited supporting field data and do not provide any understanding of the actual ecosystem integrity and functionality (Thompson *et al*. 2013).

Due to its high dependence on natural resources for economic development, Kenya is vulnerable to the effects of climate change. Although the country is not a major emitter of greenhouse gases that cause climate change, it has a huge potential to mitigate climate change by storing substantial carbon stocks in its natural forests, woodlands, bamboo forests and plantations (Republic of Kenya, 2019). Despite Kenya having a low level of forest cover the nation has still initiated measures to conserve, develop and manage its forests sustainably and has established mechanisms which allow for its forests to contribute to REDD+ planning and carbon emission reduction (Oeba *et al*., 2018). REDD+ is one aspect of the country's plan to achieve the target of restoring 10% forest cover by 2030, this mechanism also offers a key incentive to protect forests and reduce deforestation across the country (Republic of Kenya, 2019). However, Kenya's forests also serve many other purposes. For local communities they are a source of wood for construction and fuel. For the nation, they provide an environment for the establishment of plantations and industrial scale forestry – specifically focused on Pine, Cypress and *Eucalyptus*. These plantations are crucial for both economic and social development (Oeba *et al*., 2018).

The current report aims to quantify the carbon stocks in the aboveground, below-ground and dead wood pools (>10 cm in diameter only) of the vegetation in and around the Nairobi to Mau Summit Local Assessment Area.

3 METHODS

3.1 BACKGROUND

The Intergovernmental Panel on Climate Change (IPCC) has created guidelines to assess carbon stocks and their changes. The current report is based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Eggleston *et al*. 2006), which integrated and elaborated on the Revised 1966 IPCC Guidelines for National Greenhouse Inventories (Houghton *et al*. 1997), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Penman *et al*. 2000) and Good Practice Guidance for Land Use, Land-Use Change and Forestry (Penman *et al*. 2003). Volume 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Eggleston *et al*. 2006) provides guidance for preparing greenhouse gas inventories in the Agriculture, Forestry and Other Land Use (AFOLU) sector.

The IPCC guidelines make use of a three-tiered approach for reporting on carbon stocks and changes in stocks (Eggleston *et al.* 2006) although a combination of tiers can also be used for reporting.

- Tier 1 methods provide coarse estimates of the relevant parameters and rely on global default values and equations (see for example Eggleston *et al*. 2006).
- Tier 2 uses the same methodological approach as Tier 1 but applies country- or region-specific data with a higher temporal and spatial resolution.
- Tier 3 methods rely on high-resolution activity data and may include comprehensive field sampling.

The current report relies on quantitative data collected in the field and could therefore be considered as a Tier 3 approach. However, the allometric equations applied for the calculations have not been developed for the particular study area and this is considered by some authors as inadequate for Tier 3 and rather representative of Tier 2. Within the Tier system, Tier 3 estimates provide greater certainty than lower tiers.

The resources considered in this report (Appendix A) are the biomass (aboveground and belowground biomass) and a portion of the dead organic matter (dead wood >15 cm in diameter). Because no litter or soil samples were collected on site, these pools have not been included in the carbon stock estimates. The estimates provided in this report can be regarded as a baseline of the carbon stocks in 2021.

3.2 BIOMASS SAMPLING PROCEDURE

Whilst biomass sampling was part of the sampling approach on all sites visited by the botanical investigation team, because of the cut-off diameter set at 10 cm DBH (standard for this type of work, see Bastin et al., 2015), biomass sampling could only be undertaken at 90 of the 181 sites selected to survey the vegetation component for the biodiversity baseline investigation conducted in the Nairobi to Mau Summit Local Assessment Area in February and April 2021. These sites covered nine habitat types (Figure 1a for the broad overview and 1b for the specific Local Assessment Area overview).

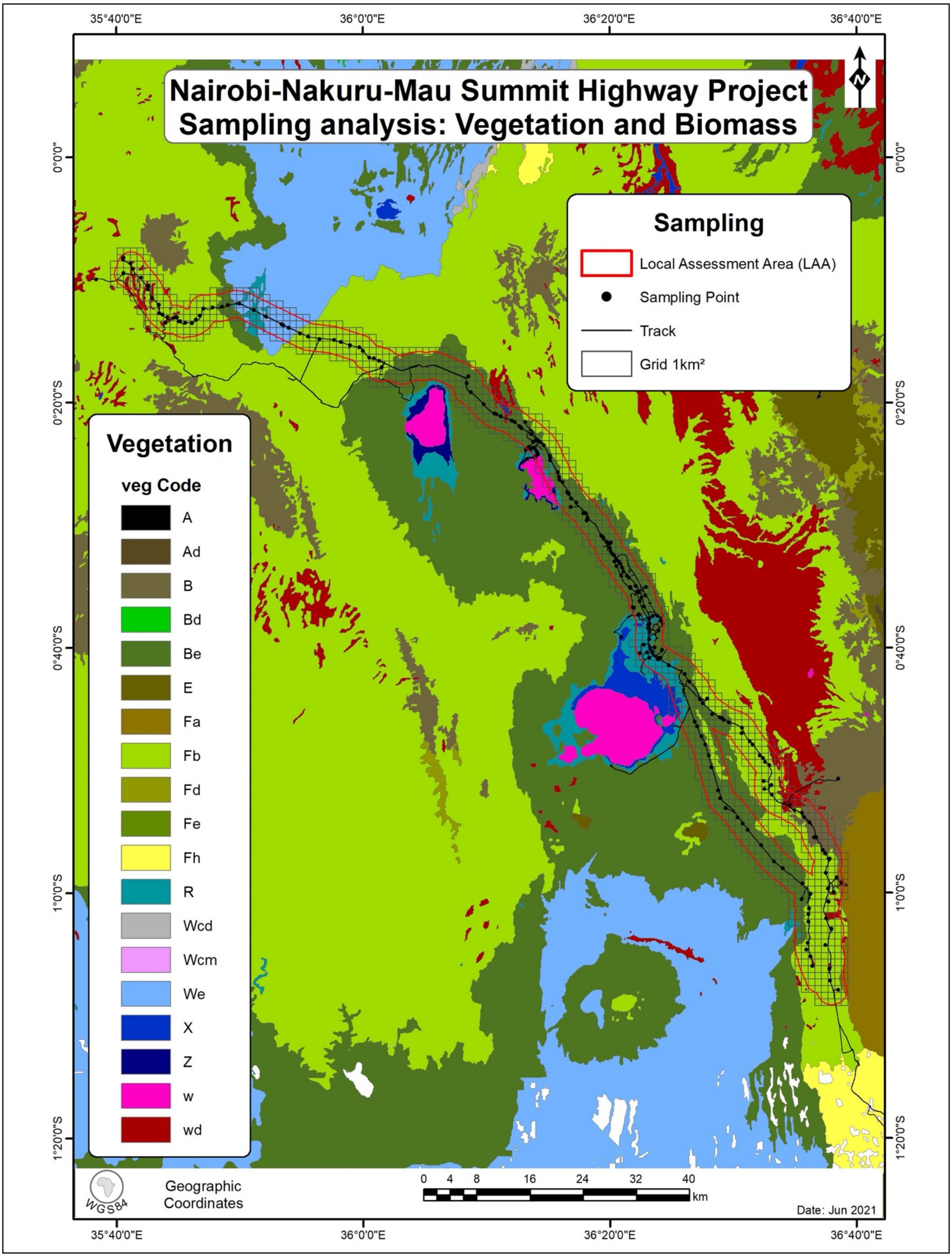
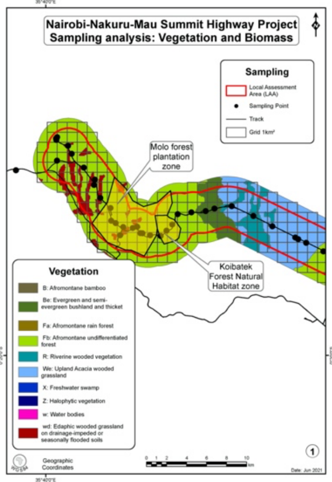


Figure 1a) general overview of the vegetation separation in theoretical broad habitat types according to VECEA.



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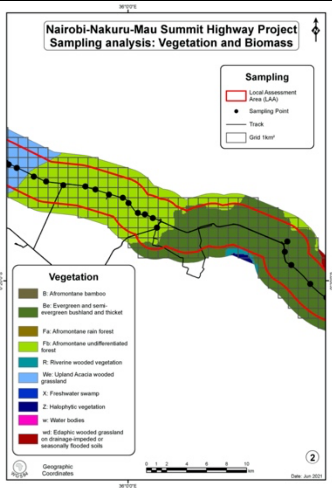

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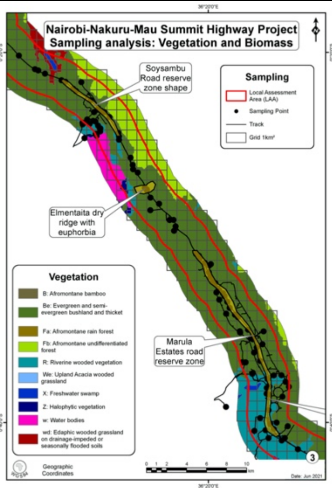

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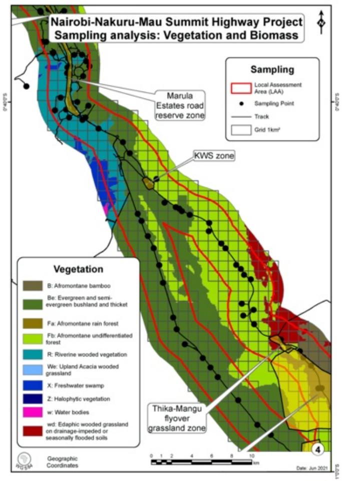

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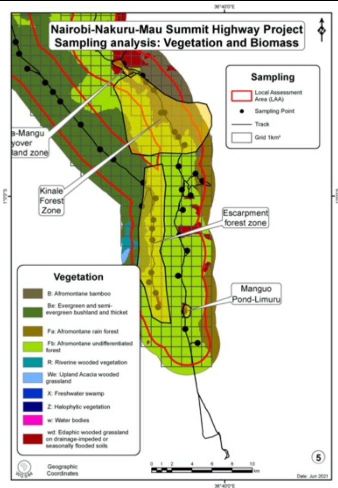


iv)

Figure 1b: Representation of the habitat types described for the Nairobi to Mau Summit Local Assessment Area, Kenya.

At each of the woody biomass survey sites a representative 60 m x 10 m area (Newton, 2007) was demarcated and the start position recorded with a global positioning system (Garmin GPS Oregon – WGS 84 datum).

For each individual tree or shrub in a plot the following was recorded:

- species name;
- whether the individual was alive or dead;
- stem diameter (in cm, 1 cm increments) measured at breast height (DBH: 1.37 m above ground level). In the current study only individuals with a stem diameter at breast height (DBH) of ≥15 cm was measured. In instances where there was a distinct main stem that had branched below DBH, the stem diameter was measured just above the basal swelling;
- tree height and canopy diameter (in m, 1.0 m increments) for live trees;
- stem diameter and height were recorded for standing dead trees;
- for large logs lying on the ground, stem diameter equivalent to DBH for standing tree (if ≥15 cm) and length were measured. All logs of qualifying size encountered along the plot were sampled, irrespective of their possible origin outside the plot.

No biomass was measured for the herbaceous components i.e., grasses and forbs.

3.3 DATA ANALYSIS

3.3.1 Aboveground biomass

Several allometric equations are available to determine the biomass of trees. Overall, it has been demonstrated that the most important predictors of the aboveground biomass of a tree, in decreasing order of importance, are trunk diameter, wood specific gravity, total height and forest type (Chave *et al*. 2005).

Chave *et al*. (2005) provide allometric equations, incorporating all these variables, for dry tropical zones (annual rainfall <1500 mm and dry season lasting >5 months per year); moist tropical zones (regions receiving ca. 1500 – 3500 mm annual rainfall and having a marked dry season lasting 1 – 4 months); and wet tropical zones (annual rainfall >3500 mm and no seasonality). Baseline monitoring at the Nairobi-Mau Summit site shows between 1740-1940 mm rainfall and are two dry seasons between June and October and between December and March. The region is therefore best represented as a moist tropical zone.

However, the ''global'' models for tropical zones, developed by Chave *et al*. (2005), are based entirely on data from outside Africa and were therefore considered not to be ideal. Mugasha *et al*. (2013) developed allometric models for prediction of above- and belowground biomass of trees in the miombo woodlands of Tanzania, which has a similar climate to the Nairobi-Mau Summit site. Indeed, several of the species sampled by Mugasha *et al*. (2013) belong to the same genera (often the same species) as those occurring in the study area i.e., *Searsia, Albizia, Acacia* (*Vachellia* and *Senegalia*) and *Ficus*.

The allometric equations of Mugasha *et al*. (2013) were therefore considered more appropriate to the current study site than the equation for dry tropical forest of Chave *et al*. (2005). Mugasha *et al*. (2013) compared the biomass derived by their equation with that of Chave *et al*. (2005) as well as that of Chamshama *et al*. (2004) (Figure 2). The equation of Mugasha *et al*. (2013) yields somewhat higher biomass values than those of Chave *et al*. (2005) and Chamshama *et al*. (2004). It was, however, somewhat lower than the estimates of Ryan *et al*. (2011) for the miombo woodlands in Mozambique. The allometric model of Ryan *et al*. (2011) was derived from a small range of stem diameters and can thus not be confidently applied to trees with a diameter at breast height of >70 cm.

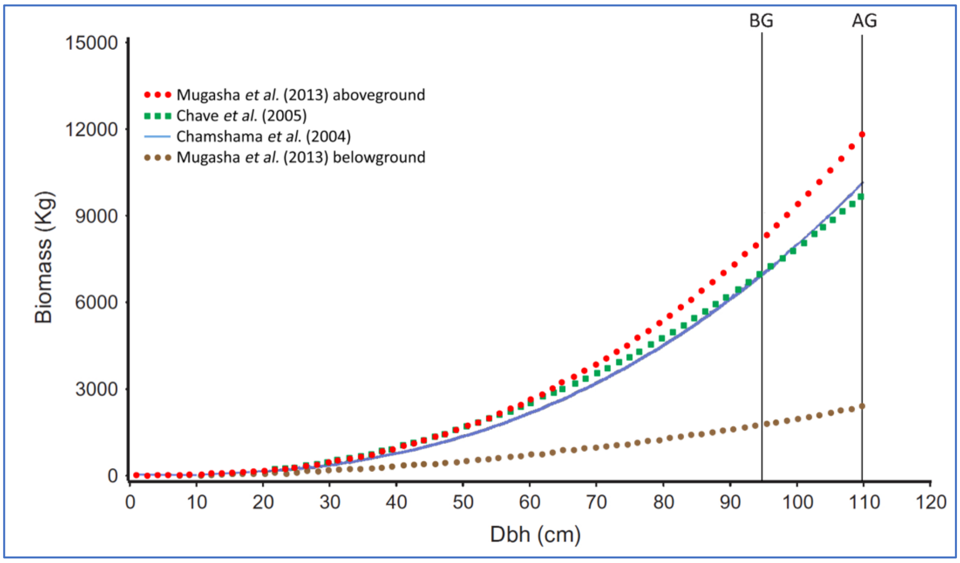


Figure 2: Biomass (dry mass) over diameter at breast height (DBH) based on the general models of Mugasha *et al*. (2013) (above- and belowground), the models developed by Chave *et al*. (2005) (aboveground) and Chamshama *et al*. (2004) (above ground). BG and AG are the maximum DBH for below- and aboveground data of Mugasha *et al*. (2013) respectively (Van Rooyen and Van Rooyen 2018 as adapted from Mugasha *et al.* (2013))

The allometric equations selected for the current report used both diameter at breast height and height as independent variables. Based on the preferred models of Mugasha *et al*. (2013), the following equation was thus selected for the current report:

For aboveground (AG) biomass:

$$AG = 0.0763 \times D^{2.2046} \times H^{0.4918}$$

Where AG equals aboveground biomass (kg) and D = diameter at breast height (cm) and H = tree height (m).

This equation is reported to be valid for diameter values ranging from 5 – 110 cm and with few exceptions most data were within this range.

Most of the published allometric equations depend on a value for the diameter at breast height to calculate biomass. If, however, the tree is branched below breast height a simple measurement at breast height is no longer possible. Chamshama *et al*. (2004), working in the same miombo system in Tanzania as Mugasha *et al*. (2013), provided allometric equations for tree diameters measured at the base of the tree. For those individuals that could not be measured at breast height, but were measured above the basal swelling, the equation of Chamshama *et al*. (2004) valid at that height was thus applied:

$$AG = 0.018 \times D^{2.839}$$

Where AG equals aboveground biomass (kg) and D = basal diameter at breast height (cm).

The dry biomass was calculated for each woody individual in a plot and the sum obtained for the total plot.

3.3.2 Belowground biomass

Estimating belowground biomass is labour-intensive and time-consuming (Cairns *et al*. 1997) and most studies use root-to-shoot ratios to estimate belowground (BG) biomass (Mokany *et al*. 2006). Since an allometric equation for belowground biomass was however provided by Mugasha *et al*. (2013) the following equation was applied to estimate the belowground biomass:

$$BG = 0.1766 \times D^{1.7844} \times H^{0.3434}$$

Where BG equals belowground biomass (kg) and D = diameter at breast height (cm) and H = tree height (m). Belowground biomass was not calculated for standing dead trees.

3.3.3 Standing dead trees

Standing dead trees for the most part, consisted only of the trunk. The volume of these stumps was calculated as a cylinder. This volume value was converted to dry mass using a mean wood density for species from tropical Africa (580 kg m^{-3}, Brown 1997).

3.3.4 Dead wood

To obtain the dry mass of the lying dead logs (part of the coarse woody debris) the volume was calculated as a cylinder. This volume value was converted to dry mass using a mean wood density for species from tropical Africa (580 kg m^{-3}, Brown 1997).

3.3.5 Basal Area (BA)

Basal area was calculated from the stem diameter values and expressed as m^2 per ha.

3.3.6 Conversion of dry tree mass to carbon mass

Studies of the carbon content of tree mass have suggested that it does not vary greatly between different species or in different parts of a plant. Extensive studies in Australia on a variety of tree species showed that aboveground dry mass generally contains 50% carbon, whereas roots contain 49% (Gifford 2000). A mean value of 50% carbon per dry mass was applied in this study for the aboveground, belowground, litter and debris carbon pools.

3.3.7 Conversion of carbon to carbon dioxide equivalent (CO_2 eq)

Carbon emission and offsets are often reported as the full molecular mass of CO_2 rather than the atomic mass of carbon. The molecular mass of CO_2 can be obtained by multiplying the atomic mass of carbon by 3.67 (McPherson & Simpson 1999). These values can be used to attach a monetary value to the carbon contained in the various associations.

3.3.8 Size class distributions of the woody strata per habitat class and per species

For each association, the frequency of occurrence of all individuals, regardless of species, in the different diameter and height classes was analysed as a first overview of the stem size class distribution to gauge the population health in general (Gaugris and Van Rooyen, 2007). Further to this, the size class distributions (SCD) per species was analysed across the entire Local Assessment Area and not per association for species where at least 30 stems were sampled (Gaugris and Van Rooyen, 2007). Stem diameters were classified into 12 stem diameter classes spanning the range of stem size classes found at the general study area level.

The diameter size class distribution curves were examined visually to classify the population into one of four population structure types (Figure 3), following the adaptation developed by Gaugris and Van Rooyen (2007) of a model developed earlier by Peters (1996).

- Type I size class distribution follows an inverse J-shaped curve, which represents the ideal curve shape for a species in a natural environment. This curve shape displays a constant decrease in the number of individuals as the size classes increase and spans the whole range of size classes described for the species (Peters

1996). Type I represents a growing population.

- Species with a Type II size class distribution have near ideal population structures but differ from a Type I only by having a lower abundance of smaller size classes. Past these smallest size classes, the size class distribution resumes a typical Type I inverse J-shape. Populations with this size structure generally represent secondary species that typically produce small numbers of seedlings (Gaugris and van Rooyen, 2007; Peters, 1996).
- Type III size class distribution is typically associated with disturbance. This size class distribution curve broadly resembles a Type I size class distribution but applies to populations where a section of the curve spanning one or several size classes is missing or where abundance is lower than expected. The typical large pool of small-sized individuals is generally missing (IIIb) and the size class distribution shows a succession of minor peaks, even with some gaps where one or several size classes may be missing altogether (Gaugris and Van Rooyen, 2007).
- The Type IV curve represents tree species with abnormal size class distribution, where only one or two peaks are observed over a restricted range of size classes. The curve is either bell-shaped with a peak more and less in the middle, or it shows a high frequency of large size classes, with little or no representation of smaller classes (Peters, 1996).

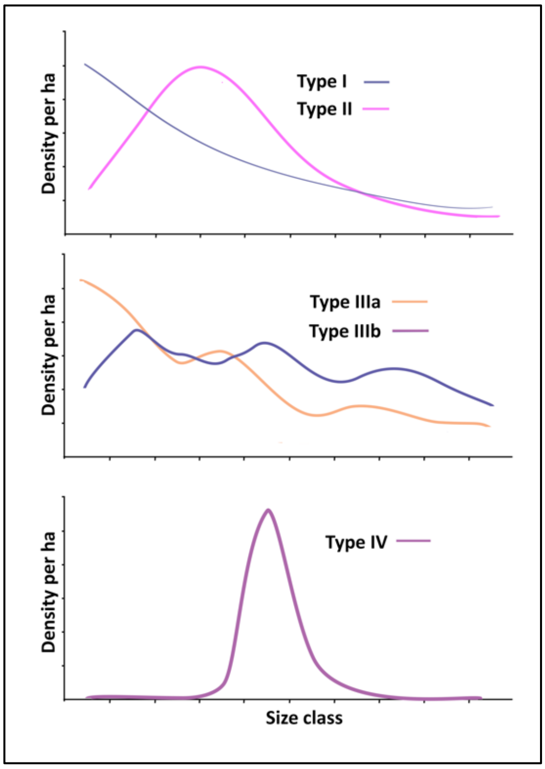


Figure 3: Idealised shapes of population curves (Van Rooyen *et al*. 2018b)

4 RESULTS

4.1 ANALYSIS OF CARBON PER HABITAT CLASS

A total of 2,307 living trees and 306 dead trees were measured in 90 plots. A total of 62 woody species were recorded. The most numerous species were *Acacia xanthophloea*, *Cupressus lusitanica*, *Eucalyptus grandis*, *Tarchonanthus camphoratus*, *Eucalyptus camaldulensis* and *Pinus patula* (Table 1). Collectively, these six species accounted for over 78% of all individuals measured.

Table 1: The plant species contributing to more than 1% of all the measured individuals in the 90 plots surveyed at the Nairobi to Mau Summit site.

Tree species	Percentage of all individuals
Acacia xanthophloea	21.86%
Cupressus lusitanica	21.75%
Eucalyptus grandis	13.35%
Tarchonanthus camphoratus	12.78%
Eucalyptus camaldulensis	6.07%
Pinus patula	2.75%
Acacia mearnsii	1.98%
Acacia gerrardii	1.91%
Schinus molle	1.76%
Juniperus procera	1.72%
Dombeya burgessiae	1.68%
Sub-total	**87.60%**

Mean basal area (Table 2) ranged from 2.6 m^2 in Upland Acacia wooded grasslands to 40.3 m^2 in Afromontane bamboo habitat.

Mean density of live stems (≥10 cm DBH) ranged from 30.0 stems per hectare in the upland Acacia wooded grassland habitat to 506.7 stems per hectare in the Afromontane bamboo habitat. Mean density of dead stems (≥10 cm DBH) ranged from 0.0 stems per hectare in the upland Acacia wooded grassland and edaphic wooded grassland habitats to 433.3 stems per hectare in the Afromontane rainforest habitat.

Mean stem diameter at breast height of the live trees measured was lowest in the upland Acacia wooded grassland with an average of 18.9 cm and was highest around water bodies where the average was 36.8 cm; just 0.2 cm larger than the mean live tree DBH of the Afromontane rainforest areas. Mean of dead tree DBH was lowest in the evergreen and semi-evergreen bushland and thicket habitats at 30.4 cm and was highest in the halophytic vegetation habitat class at 50.6 cm. Mean tree height was lowest in the upland Acacia wooded grassland habitat at 7.1m and was highest in the Afromontane rainforest areas at 14.8 m. The lowest mean of the widest canopy dimension was found in the Afromontane undifferentiated forest habitat at 5.1 m and was highest in the riverine wooded vegetation and upland acacia wooded grassland habitats at 7.6 m each (Table 2).

Aboveground carbon in live trees ranged from 2 tonnes in the upland acacia wooded grassland habitat to 170.2 tonnes in the Afromontane rainforest habitat. Belowground carbon in live trees followed a similar pattern, with the lowest total found in upland acacia wooded grassland habitats (1 tonne) and the highest, 56.7 tonnes, found in Afromontane rainforest habitats. In the upland acacia wooded grassland habitats and the edaphic wooded grassland habitats there was zero carbon mass in dead wood, however in the Afromontane rainforest sites 33.4 tonnes was recorded (Table 3, Figure 4).

Table 2: Mean basal area, tree density, diameter and height of woody individuals (≥15 cm DBH) in the various habitat types in the Nairobi to Mau Summit Local Assessment Area, Kenya

Habitat types	Mean basal area in m² per ha	Mean of density of live stems ≥15 cm DBH per ha	Mean of density of dead stems ≥15 cm DBH per ha	Mean of live tree DBH (cm)	Mean of dead tree diameter (cm)	Mean of tree height (m)	Mean of base of canopy height (m)	Mean of widest canopy dimension (m)
Afromontane bamboo	40.3	506.7	190.0	28.9	33.5	14.3	7.7	5.8
Afromontane rainforest	35.0	400.0	433.3	36.5	34.9	14.8	10.2	4.9
Afromontane undifferentiated forest	28.5	277.2	34.1	23.3	31.6	11.9	6.0	5.1
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	12.1	127.8	0.0	28.1		12.6	7.7	6.7
Evergreen and semi-evergreen bushland and thicket	13.8	151.1	3.1	20.3	30.4	7.8	3.1	6.4
Halophytic vegetation	6.2	143.3	16.7	29.5	50.6	11.5	7.0	7.5
Riverine wooded vegetation	19.9	214.8	14.3	30.5	40.1	10.0	4.2	7.6
Upland Acacia wooded grassland	2.6	30.0	0.0	18.9		7.1	1.9	7.6
Water bodies	4.0	216.7	133.3	36.8	32.8	10.2	5.5	7.3
Total	**23.4**	**2,067.6**	**824.8**	**252.8**	**253.9**	**100.1**	**53.4**	**58.8**
Max	2.6	506.7	433.3	36.8	50.6	14.8	10.2	7.6
Min	40.3	30.0	0.0	18.9	30.4	7.1	1.9	4.9

Table 3: Mean number of woody species, biomass above ground (AGB) and below ground (BGB per relevé, including carbon biomass of dead trees encountered in the Nairobi to Mau Summit Local Assessment Area, Kenya.

Habitat types	Sum of Relevé distinct area sampled in m²	Mean number of woody species noted per relevé	Mean for live Carbon mass AGB per ha (tonnes)	Mean for live Carbon mass BGB per ha (tonnes)	Mean for dead tree Carbon mass per ha in tonnes	Total mean carbon mass per ha (tonnes)
Afromontane bamboo	2400.0	2.8	130.2	46.2	5.5	181.9
Afromontane rainforest	600.0	1.0	170.2	56.7	33.4	260.3
Afromontane undifferentiated forest	18100.0	2.6	51.4	17.7	1.2	70.3
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	600.0	2.0	37.5	12.5	0.0	50.0
Evergreen and semi-evergreen bushland and thicket	21100.0	1.9	23.7	7.4	0.2	31.3
Halophytic vegetation	1200.0	1.0	40.0	13.5	6.5	60.0
Riverine wooded vegetation	9025.0	1.6	91.0	25.5	5.0	121.5
Upland Acacia wooded grassland	600.0	1.0	2.0	1.0	0.0	3.0
Water bodies	600.0	1.0	72.5	25.1	23.2	120.7
Total	**54,225.0**	**14.8**	**618.5**	**205.4**	**75.0**	**898.9**
Max	21,100.0	2.8	170.2	56.7	33.4	260.3
Min	600.0	1.0	2.0	1.0	0.0	3.0

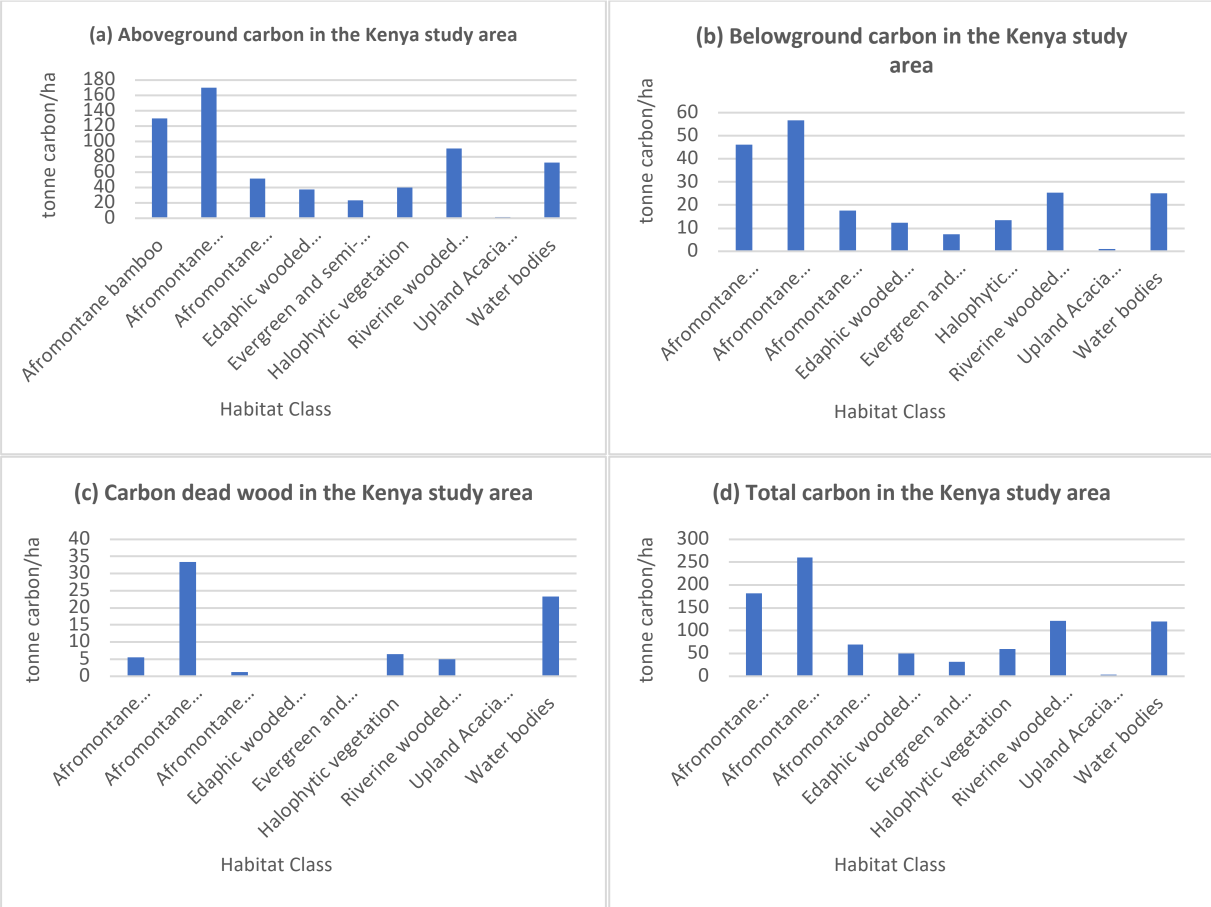


Figure 4: Comparison of (a) aboveground carbon per ha; (b) belowground carbon per ha; (c) carbon in dead wood per ha; and (d) total carbon in aboveground, belowground and dead wood per ha per habitat class in the Nairobi-Mau Summit Local Assessment Area, Kenya.

Mean aboveground carbon mass for the Nairobi to Mau Summit Local Assessment Area was highest in the Afromontane rainforest at 624.6 t CO_2/ha and was lowest in the upland Acacia wooded grassland habitat at 7.5 t CO_2/ha. Mean belowground carbon mass for the Local Assessment Area followed the same trend, with 208 t CO_2/ha recorded in the Afromontane habitats and 4.7 t CO_2/ha recorded in the upland Acacia wooded grassland habitat. Furthermore, these trends were reflected in the carbon mass recorded in dead trees in the Local Assessment Area. Afromontane rainforest habitats had 122.7 t CO_2/ha and both upland Acacia wooded grasslands and edaphic wooded grasslands had 0 t CO_2/ha. Based on these figures, the greatest release value therefore lay in the Afromontane rainforest habitat at USD 4776.14 per ha per year. The lowest was found in the upland acacia wooded grassland habitat at USD 55.79 per ha per year (Table 4).

Table 4: Carbon dioxide (CO_2) contained in three pools in the various habitat types in the Nairobi to Mau Summit Local Assessment Area Kenya and financial importance under REDD+

Habitat types	Mean for live AGB CO_2 mass per ha (tonnes)	Mean for live BGB CO_2 mass per ha (tonnes)	Mean for dead tree CO_2 mass per ha in tonnes	Total mean CO_2 mass per ha (tonnes)	Approx. release financial value per ha per year at USD 5 per T CO2 equivalent, under REDD+, assuming complete deforestation
Afromontane bamboo	478.0	169.4	20.0	667.4	$ 3,337.08
Afromontane rainforest	624.6	208.0	122.7	955.2	$ 4,776.14
Afromontane undifferentiated forest	188.8	64.8	4.3	257.9	$ 1,289.27
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	137.7	45.7	0.0	183.4	$ 917.16
Evergreen and semi-evergreen bushland and thicket	86.9	27.3	0.7	114.9	$ 574.37
Halophytic vegetation	146.7	49.5	24.0	220.2	$ 1,100.87
Riverine wooded vegetation	333.9	93.4	18.5	445.8	$ 2,228.99
Upland Acacia wooded grassland	7.5	3.7	0.0	11.2	$ 55.79
Water bodies	265.9	91.9	85.2	443.1	$ 2,215.56
Total	**2,269.9**	**753.8**	**275.4**	**3,299.0**	**$ 16,495.23**
Max	624.6	208.0	122.7	955.2	$ 4,776.14
Min	7.5	3.7	0.0	11.2	$ 55.79

4.2 ANALYSIS OF SIZE CLASS DISTRIBUTION PER HABITAT CLASS

4.2.1 Afromontane bamboo

The stem diameter within the live biomass of the Afromontane bamboo habitat class ranged from 11 cm to 48 cm and in the dead biomass this figure ranged from 12 cm to 52 cm. Similar trends were observed in both the live and dead biomass, with few trees found in the 20-25 cm diameter class. The maximum tree height in this habitat class reached 20 m and the minimum height was 3 m, however the majority of trees were between 15 and 17m in height. Based on the stem diameters, this habitat class can be classified as Type IIIa and can thus be considered as disturbed (Figure 5).

The apparent pattern is somewhat typical of a plantation dominated system, with even aged cohorts planted at regular intervals under a similar density. Moreover, the peak in height classes highlights that majority of the plantations have reached the height of 15 – 19 m. This situation highlights the predominance of plantations within the 2 km buffer zone along the road.

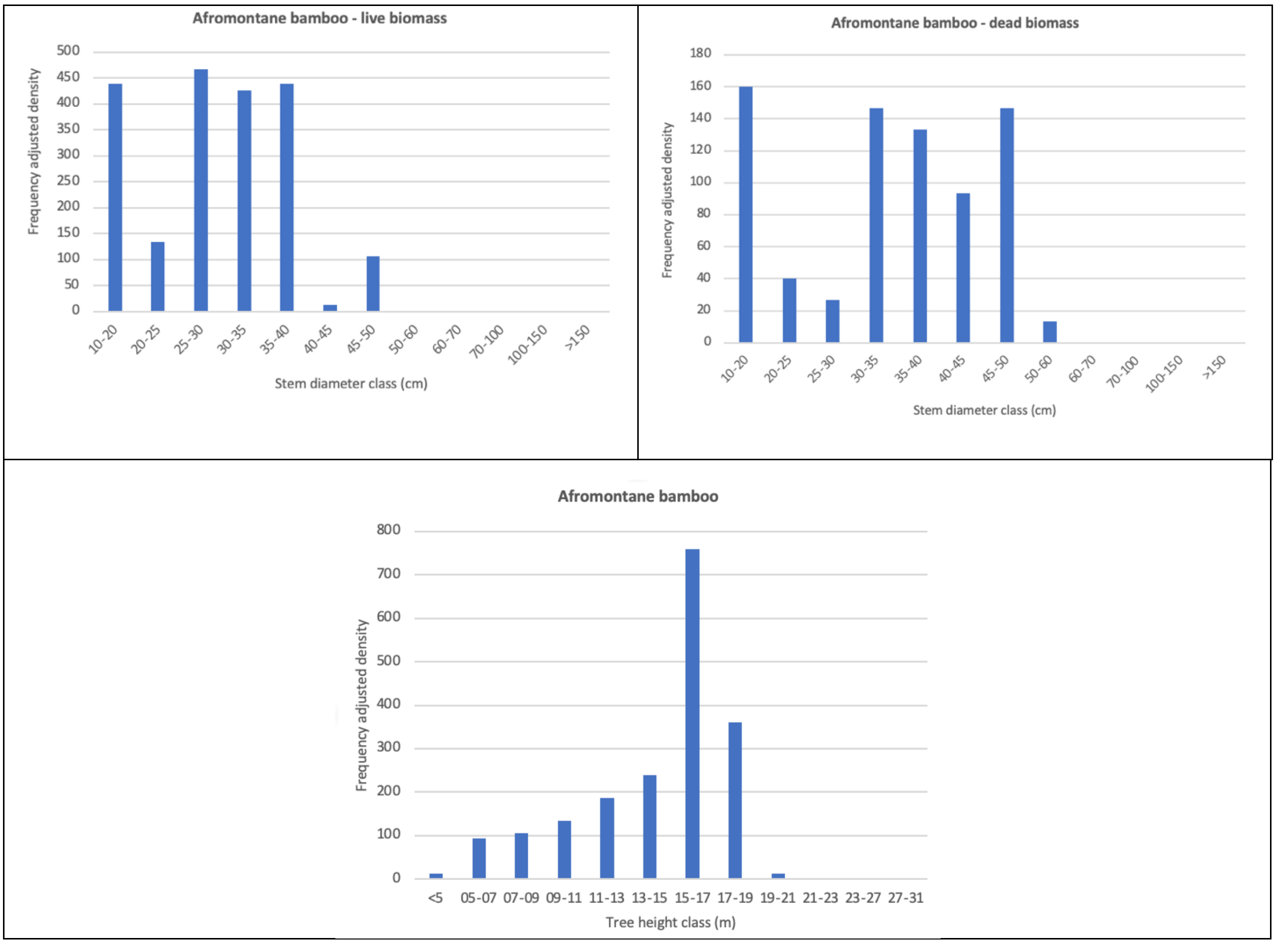


Figure 5: Stem diameter for live and dead trees and tree height in the Afromontane bamboo habitat class

4.2.2 Afromontane rainforest

Within the live biomass recorded in the Afromontane rainforest habitat class the majority of trees had stem diameters of between 30 and 40 cm, no trees had diameters below 28 cm and the maximum diameter recorded was 52 cm. Within the dead biomass, the majority of trees had stem diameters of between 30 and 35 cm. No tree had a diameter below 16 cm and, similar to the live biomass category, the largest diameter recorded was 56 cm. The maximum height of a tree recorded in the Afromontane rainforest was 18 m with the smallest tree measuring 1.5 m, however there were few recordings of trees measuring below 5 m as the majority measured between 15 and 17 m.

The vegetation of this habitat class shows a Type IV distribution which can be considered as problematic (Figure 6). Indeed the regeneration cohort is generally absent and the population of trees noted in this habitat type is likely to remain until the large old trees have died off, but they will not be replaced by new generations of the same species. It is likely that a mixture of plantation and isolated natural forest trees, probably isolated, is apparent in these curves.

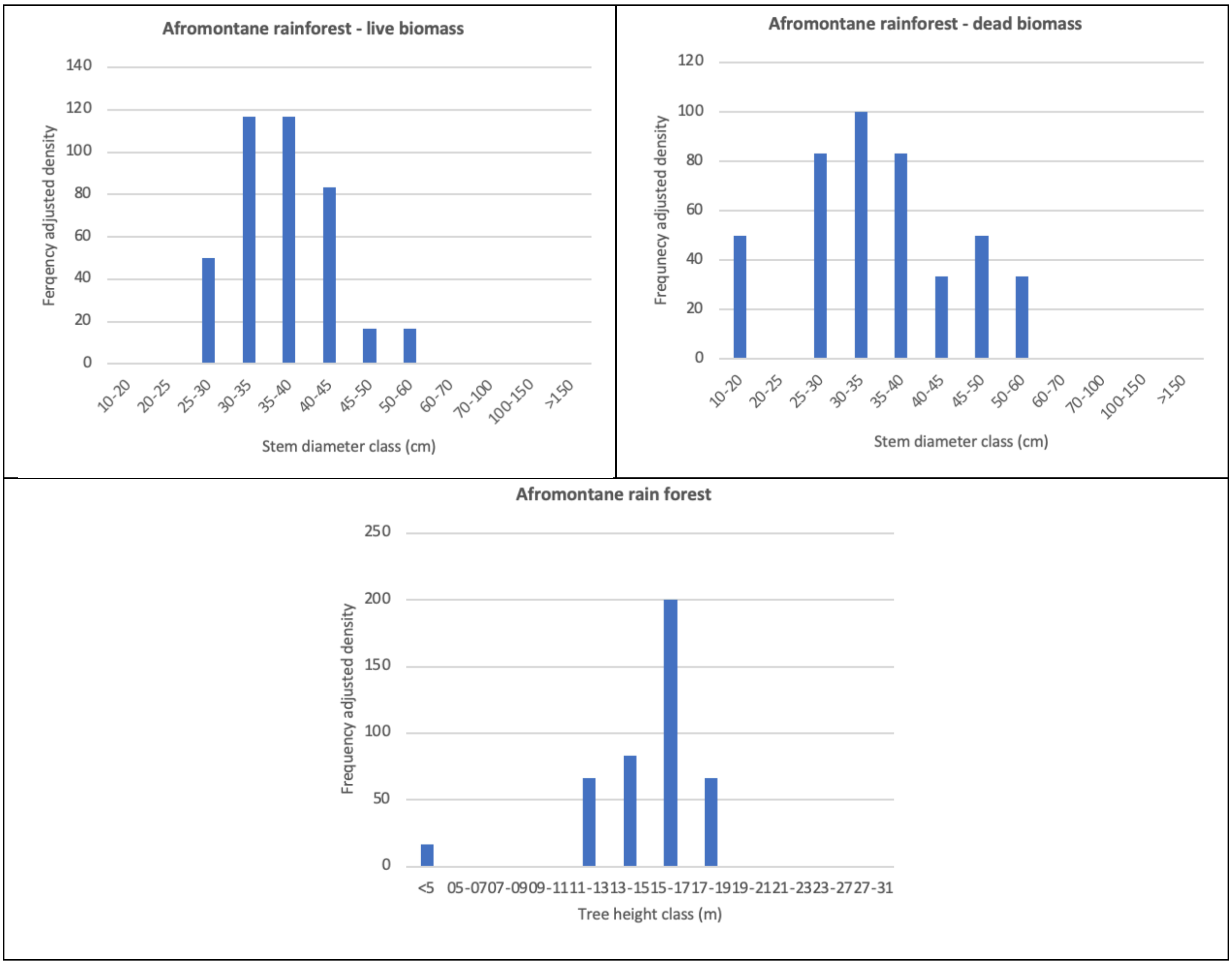


Figure 6: Stem diameter for live and dead trees and tree height in the Afromontane rainforest habitat class

4.2.3 Afromontane undifferentiated forest

Within the live biomass category, the majority of trees in the Afromontane undifferentiated forest habitat had a diameter of between 10-20 cm, however a maximum diameter of 120 cm and a minimum of 10 cm were recorded. Within the dead biomass category, the majority of trees had a diameter of between 30 and 35 cm. The smallest diameter was less than 10 cm and the largest was 85 cm. The trees within this habitat class ranged from less than 2 m tall to 24 m tall. The most populous tree height category was 15 to 17m, yet many were also recorded in the 13 to 15 m category.

The distribution of stem diameters in this habitat class indicates a type I distribution which under normal circumstances can be considered ideal and that of a growing population (Figure 7). In the present situation, the density of larger size classes with a DBH of 20 cm and more is very low relative to the density of smaller size classes. The density of stems across the height classes displays a relatively even pattern. In this case this highlights habitat types where larger trees were removed, leaving only species that are uninteresting and a surge of more pioneer species is appearing at high density, competing for light. The apparent pattern is more typical of a pioneer or secondary regrowth that may form dense stands of high thicket appearance.

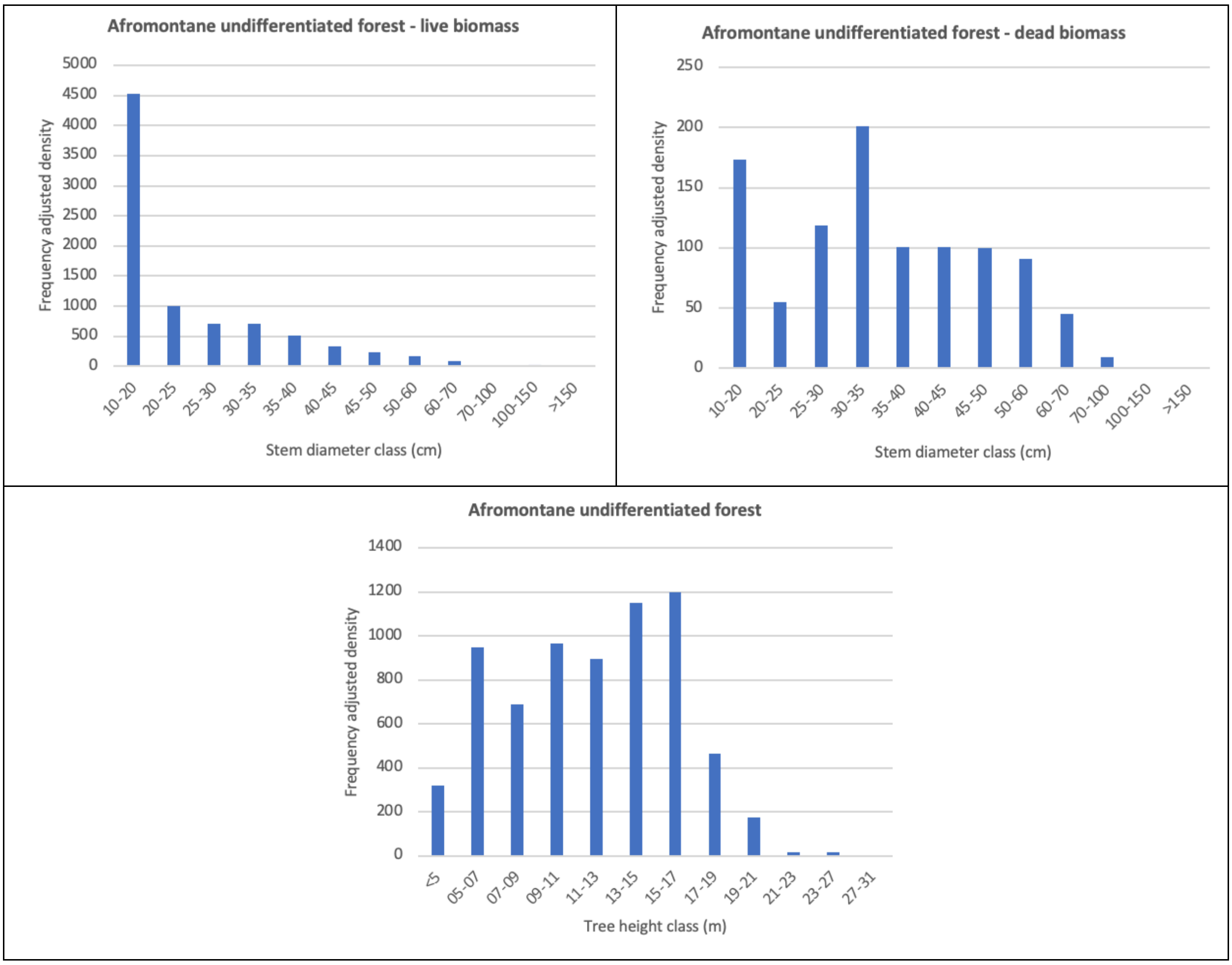


Figure 7: Stem diameter for live and dead trees and tree height in the Afromontane undifferentiated forest habitat class

4.2.4 Edaphic wooded grassland on drainage-impeded or seasonally flooded soils

The majority of live trees recorded in the edaphic wooded grassland on drainage-impeded or seasonally flooded soil had diameters of between 10 and 20 cm. The maximum diameter was 65 cm and the minimum diameter recorded as 16 cm. No dead trees were measured in this habitat class. The majority of trees were between 9 and 11 m in height, with no tree less than 8 m in height and no tree more than 22 m tall.

This habitat class represents a Type IIIa distribution in terms of the diameter of trees. The notable absence of some of the size classes may highlight selective harvesting of a cohort of species at one point in the past but may also reflect natural disturbance such as drought or flooding in the past, which may have prevented requirement for a number of years. This pattern of tree population can be considered as having been subject to either a natural or a human disturbance in the past (Figure 8). If it was a natural disturbance, the size classes concerned highlight that this event was a substantial number of years in the past. If the event was human driven, the age cannot be ascertained with precision, and it may represent an old harvesting episode or a current concern with a specific target for the large mature trees such as could be the case for precious timbers where large mature trees are selectively removed first because of the inherent value of the larger stems.

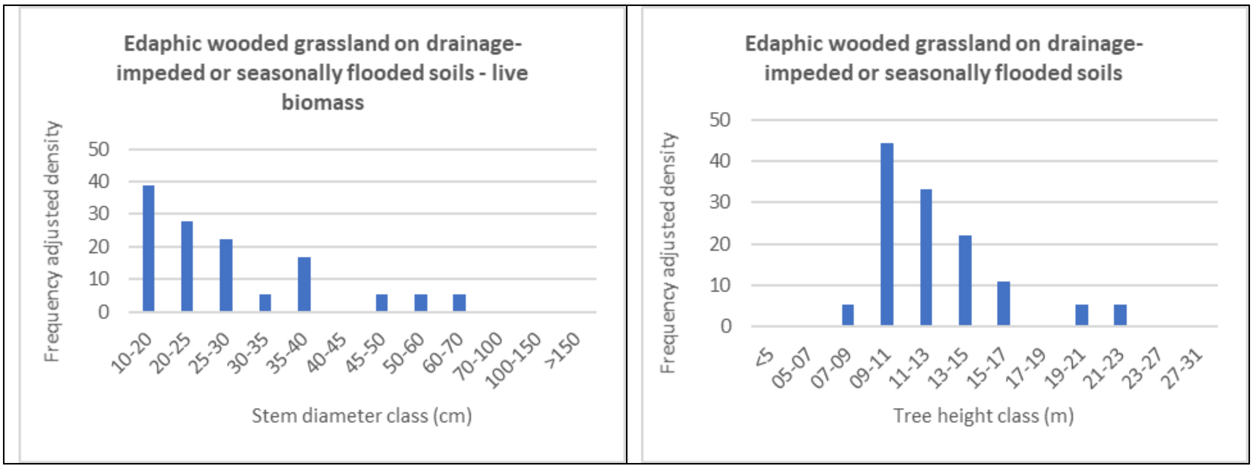


Figure 8: Stem diameter for live trees and tree height in the edaphic wooded grassland on drainage-impeded or seasonally flooded soils habitat class

4.2.5 Evergreen and semi-evergreen bushland and thicket

The majority of the live trees measured in the evergreen and semi-evergreen bushland and thicket habitat class had diameters between 10 and 20 cm, yet the maximum diameter recorded was 226 cm and the minimum diameter recorded was 10 cm. Within the dead trees measured, the majority still had a diameter of between 10 and 20 cm but there was much more variability in the measurements, with many recording a diameter of between 25 and 35 cm. The maximum diameter of a dead tree recorded in this habitat class was 76 cm and the minimum was 10 cm. The majority of trees in this habitat class were between 5 and 7 m tall, there were many trees less than 5 m in height with the smallest being 2 m tall and the largest being 18 m tall.

As for the Afromontane undifferentiated forest, the distribution of stem diameters in this habitat class favours a type I distribution which under normal circumstances can be considered ideal and that of a growing population (Figure 9). In the present situation, the density of larger size classes with a DBH of 20 cm and more is very low relative to the density of smaller size classes. The density of stems across the height classes displays also displays a pattern favouring smaller trees. In this instance the pattern is typical of a thicket vegetation where larger trees are the exception rather than the norm. The pattern fits the habitat type description and to ascertain with precision the status of the tree population in this habitat type, sampling from 5 cm DBH may be required, as well as distributing the size classes in smaller size class bins.

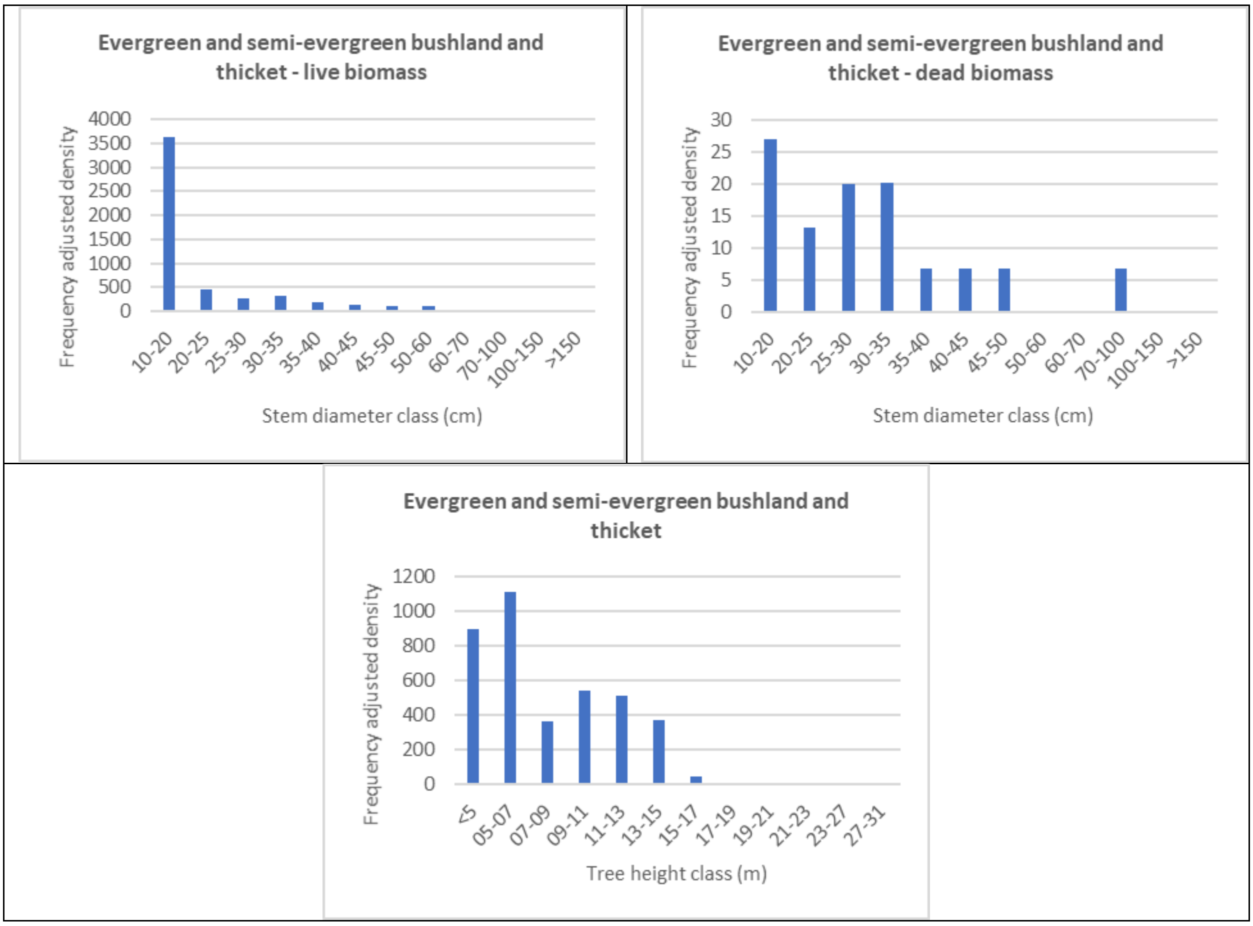


Figure 9: Stem diameter for live and dead trees and tree height in the evergreen and semi-evergreen bushland and thicket habitat class

4.2.6 Halophytic vegetation

The presence of trees in the halophytic vegetation is typically on the boundary of the habitat type where tree formation appear to naturally delineate the habitat type. Within the live biomass of the halophytic vegetation class most trees had a diameter of between 10 and 20 cm. However, the maximum diameter recorded was 68 cm and the minimum was 11 cm. Within the dead biomass, the distribution showed that there was a categorical split in the diameters of trees. The smallest diameter recorded was 24 cm and the largest recorded was 86 cm. The majority of trees in the halophytic vegetation class were between 11 and 13 m tall. The tallest tree in this environment was 16 m in height and the smallest was 1 m tall.

The distribution of tree diameters in this environment resembles that of a Type IIIa, which indicate a disturbed environment (Figure 10). The disturbance pattern can be considered as relatively muted and there are no major gaps in the pattern of stem abundance along the different size classes bins. The main apparent gap is between the DBH of 20 cm and 35 cm, where a dip in the curve is apparent. Considering the nature of the habitat type, this may be related to a natural disturbance in the past, where either drought or longer-term flooding prevented a typical recruitment pattern.

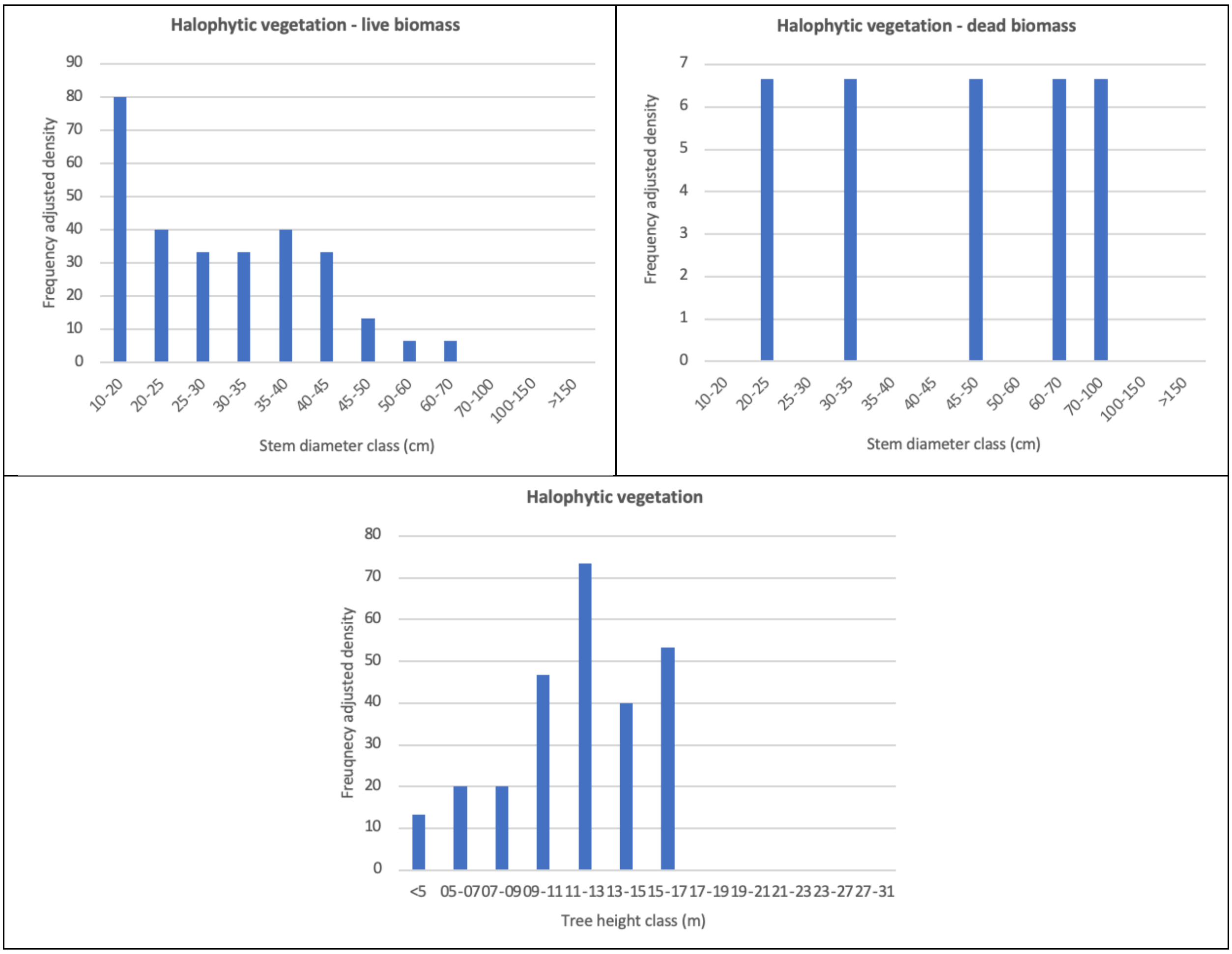


Figure 10: Stem diameter for live and dead trees and tree height in the halophytic vegetation habitat class

4.2.7 Riverine wooded vegetation

In the riverine wooded vegetation habitat class, the vast majority of live trees had stem diameters of between 10 and 20 cm, the smallest diameter recorded was 10 cm and the largest recorded was 140 cm. Within the dead biomass of this habitat class there was much more variation in the diameters recorded. With a slight majority measuring between 20 and 25 cm, the largest diameter recorded was 86 cm and the smallest was 12 cm. There was also a lot of variation in the heights of the trees in the riverine wooded vegetation habitat. The tallest tree in this environment measured 18 m and the smallest measured 0.5 m tall. Yet a large proportion of trees measured were between 5 and 11 m tall.

As for the Afromontane undifferentiated forest, the distribution of stem diameters in this habitat class favours a type I distribution which under normal circumstances can be considered ideal and that of a growing population (Figure 11). In the present situation, the density of larger size classes with a DBH of 20 cm and more is low relative to the density of smaller size classes. The density of dead stems highlights many deaths in the relatively younger age classes and a near equally pool of larger stems. The density of stems across the height classes displays a pattern favouring medium to larger trees. This highlights a vegetation type made of smaller stemmed trees reaching for height before establishing into larger stems through naturally occurring thinning. The density of smaller stems may arise from the nature of the riverine systems where water brings seeds from adjacent vegetation types through runoff, as the water passes through the riverine vegetation system, seeds are stopped and many species from adjacent systems germinate and develop, but do not reach a fully mature stage as they develop within a non-suitable habitat. This may explain the hyper abundance of smaller stemmed individuals and the substantial pool of smaller dead stems noted.

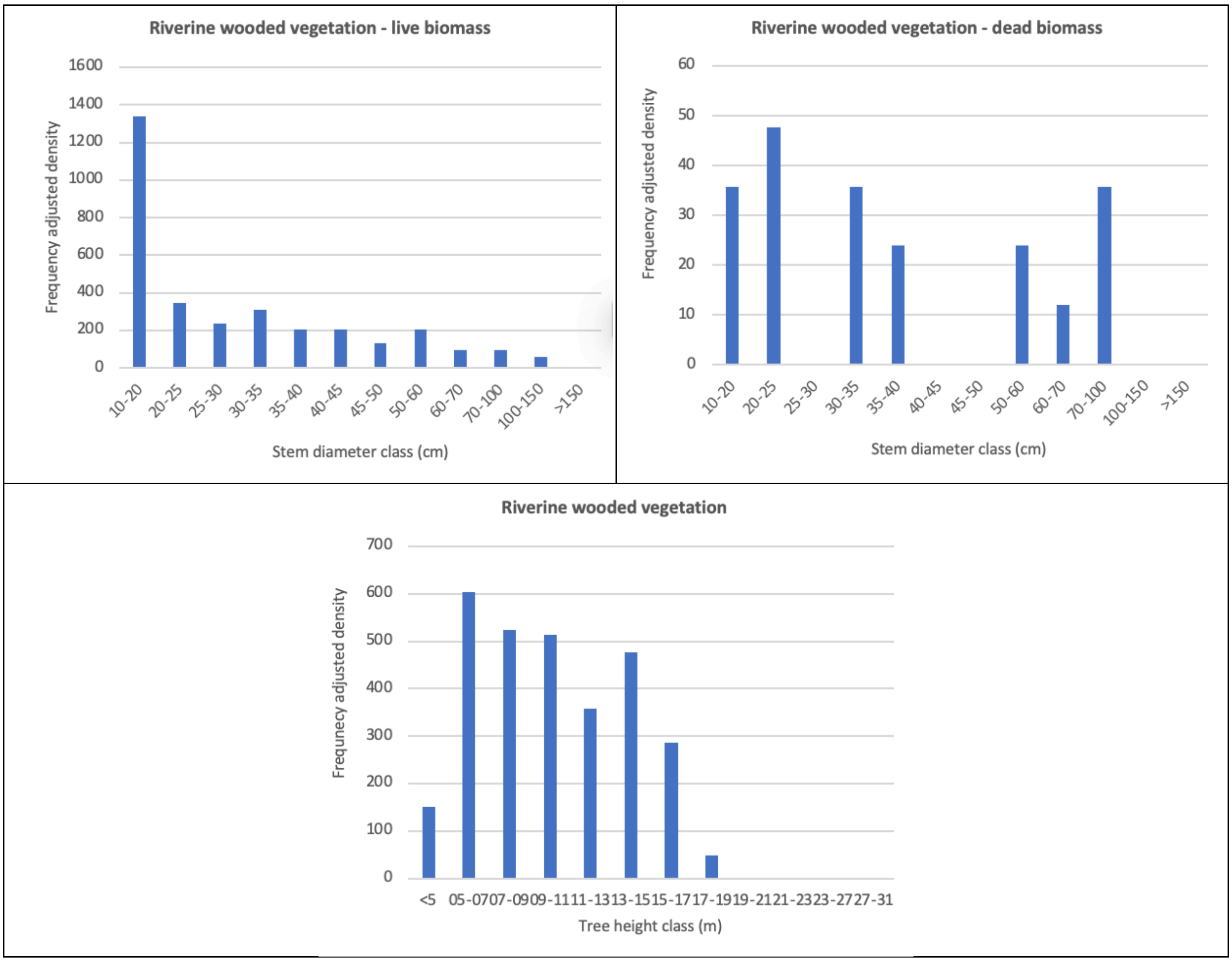


Figure 11: Stem diameter for live and dead trees and tree height in the riverine wooded vegetation habitat class

4.2.8 Upland Acacia wooded grassland

Within the upland Acacia wooded grassland habitat no trees measured had a diameter greater than 25 cm, indeed there was limited distribution with the maximum diameter measured being 24 cm and the minimum diameter recorded as 14 cm. There was no dead biomass measured in this environment. The heights of the trees recorded also showed limited distribution, with only 2 m difference between the tallest tree measured (8 m) and the smallest tree measured (6 m).

The distribution of stem diameter measurements cannot be adequately ascertained from the present representation. The current pattern highlights only two size class bins, which behave as would a Type I distribution (Figure 12). Considering the clumping of the tree diameter information in this habitat type, the use of a smaller DBH cut off may be required to better understand the woody population behaviour as well as separating the data into smaller size classes bins.

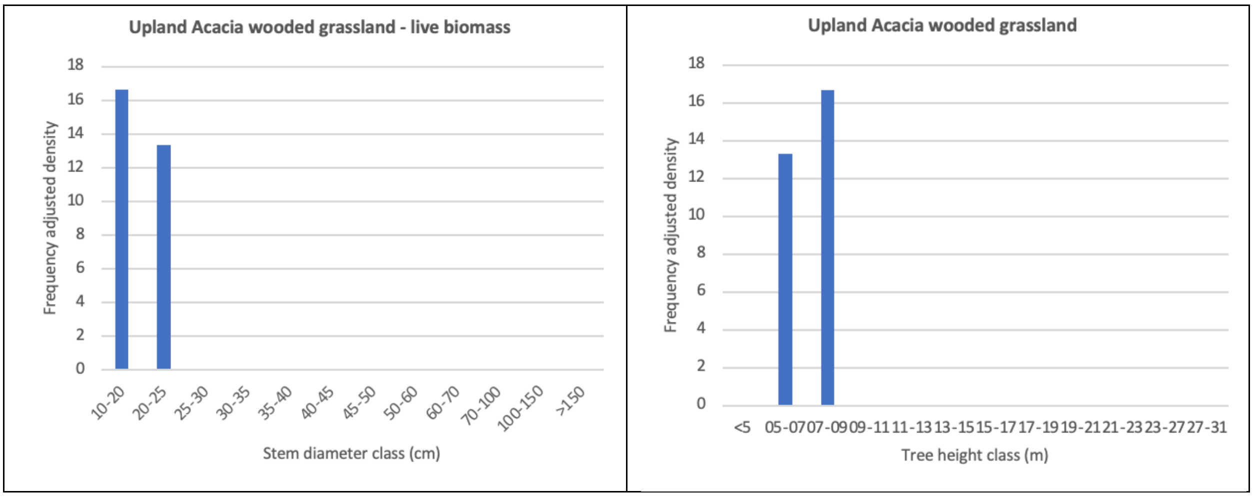


Figure 12: Stem diameter for live and dead trees and tree height in the upland acacia wooded grassland habitat class

4.2.9 Water bodies

The tree component of this habitat type is found on the fringes of the lakes and water bodies of the Local Assessment Area where extensive woodland zones may develop and progress or retreat based on the changes in levels of the lakes or water bodies. Prolonged periods of flooding will most likely kill trees established close to the lake while prolonged periods of droughts will most likely kill trees established on the outer boundaries of the habitat type.

Most stem diameters of live trees recorded in the water body habitat class measured between 30 and 35 cm, the largest diameter measured was 56 cm and the smallest was 16 cm. Similarly, within the dead biomass of the water bodies habitat class, the smallest diameter measured was 16 cm and the largest was 65 cm. The majority of the trees in this environment measured between 11 and 13 m tall, the smallest tree measured was 2 m tall and the largest was 14 m tall.

The distribution of diameters of live trees in the water body habitat class indicate a Type II distribution or an environment which is typical of the changes in water level that affect such an environment (Figure 13). As the species are adapted to the changes, the presence of a substantial density of large mature trees that can produce seeds is apparent and may be sufficient to ensure the persistence of the woody component overall. The lack of individuals in the 20 – 25 cm DBH class is however a concern as this represents a complete cohort. The status of the curve may be influenced by the level of sampling and the restricted geographic dimension of the sampling and it is possible that with a wider sampling zone for this habitat type this missing age group may not be a consistent feature.

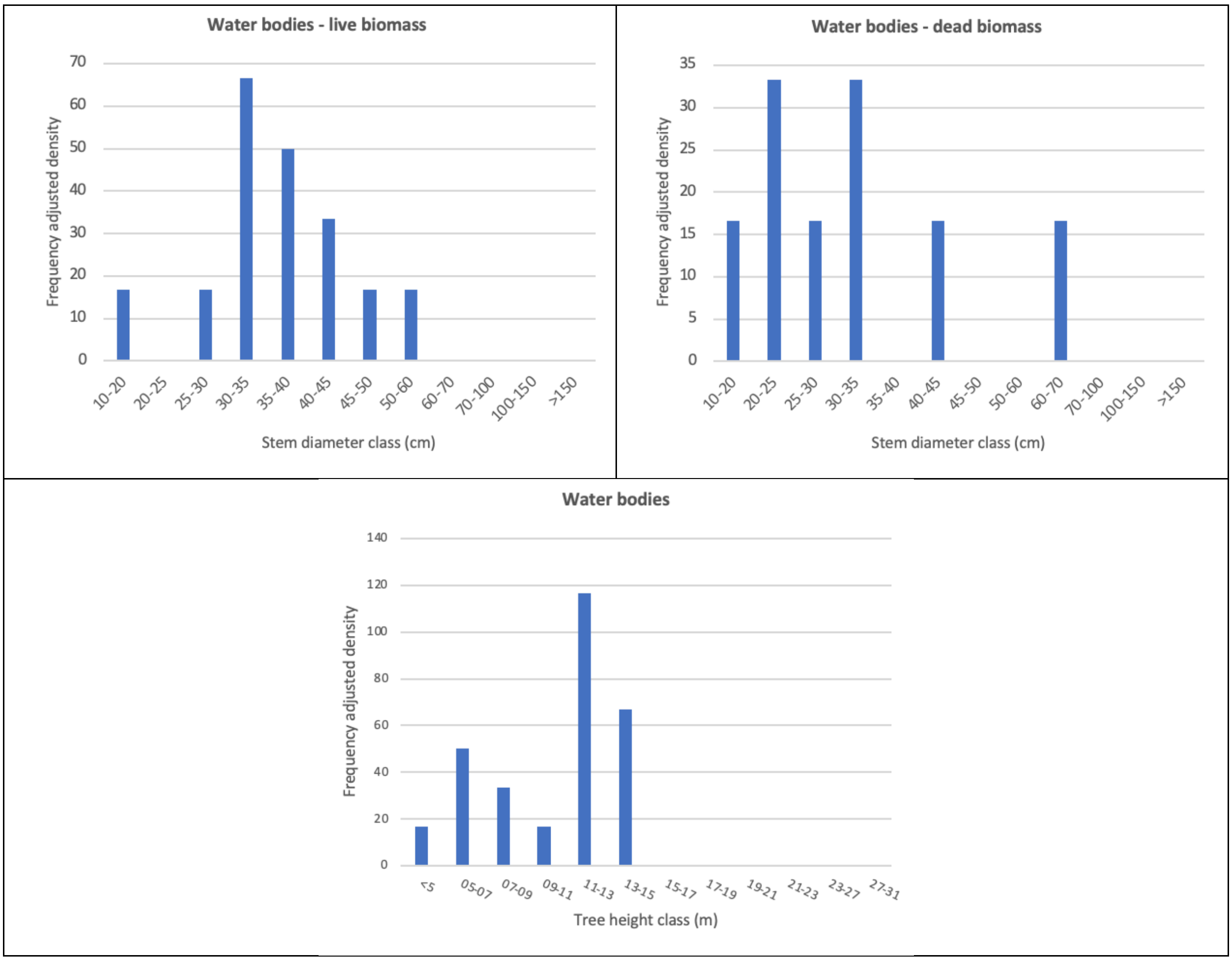
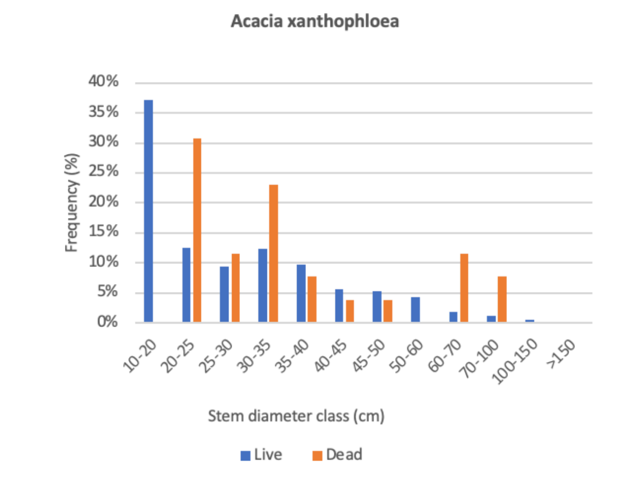


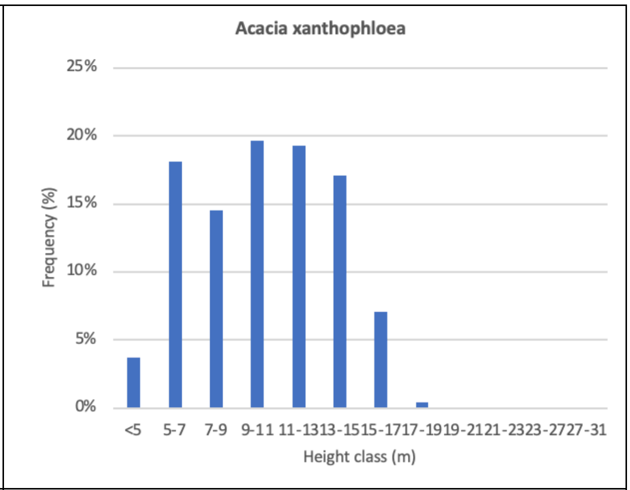
Figure 13: Stem diameter for live and dead trees and tree height in the water bodies habitat class

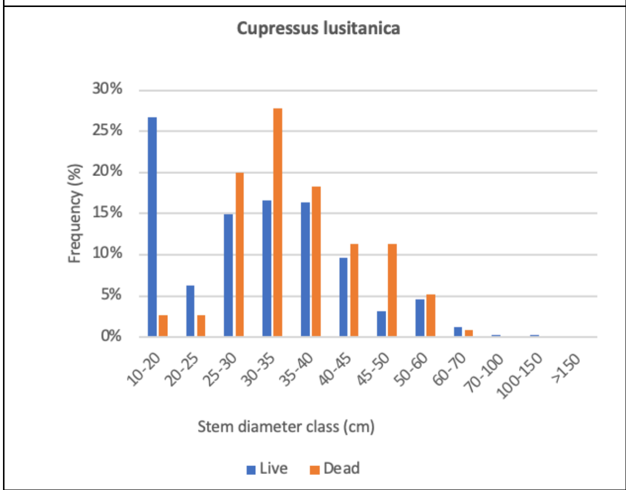
4.3 ANALYSIS OF SIZE CLASS DISTRIBUTION OF SPECIES

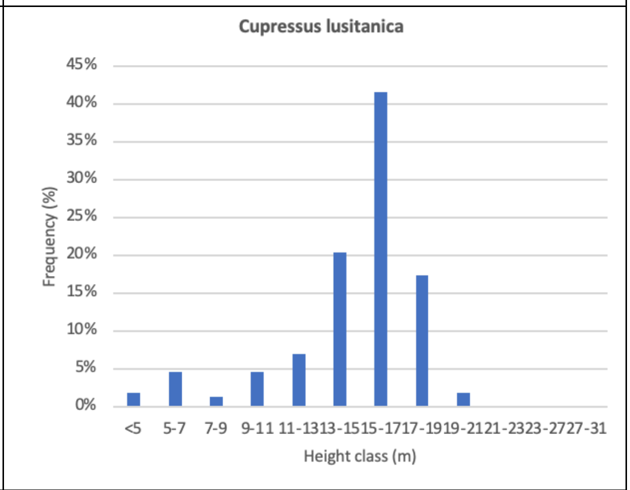
The size class distributions of only the most abundant species (at least 30 individuals sampled) are illustrated below (Figure 14). Overall, most naturally occurring species for the Local Assessment Area considered in the analysis (*Acacia xantophloea, Acacia mearnsii, Acacia gerrardii, Juniperus procera, Dombeya burgessiae, Tarchonanthus camphoratus*) displayed inverse J-curves (Type I), a result favouring healthy populations for these species at landscape level.

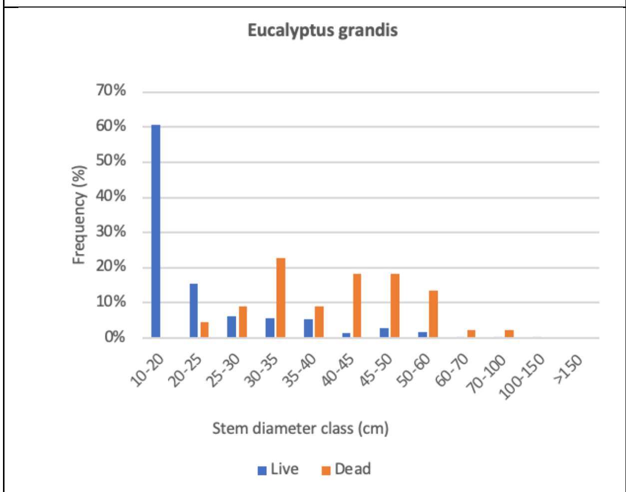
However, for some of the exotic species such as *Cupressus lusitanica* and *Pinus patula* showed Type III curves. Such a trend, in this case is more likely the result of their growth under plantations and thus the spread of the stem diameters is likely to be anthropogenically controlled. This is particularly obvious with *Cupressus lusitanica* where it is apparent that new cohort was recently planted (stems of 10 – 20 cm DBH) while another cohort has now reached a sizeable dimension around 35 cm diameter.

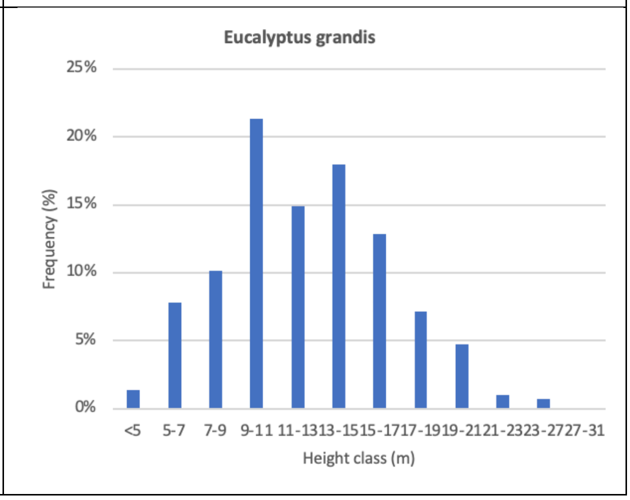

Acacia xanthophloea
Frequency (%)
40%
35%
30%
25%
20%
15%
10%
5%
0%
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead

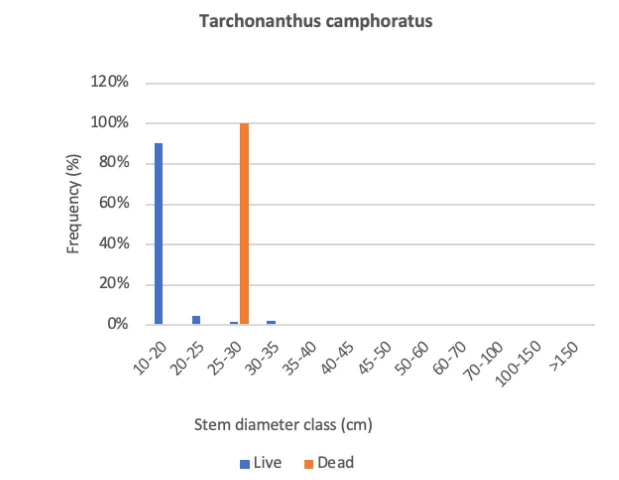

Acacia xanthophloea
Frequency (%)
25%
20%
15%
10%
5%
0%
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)

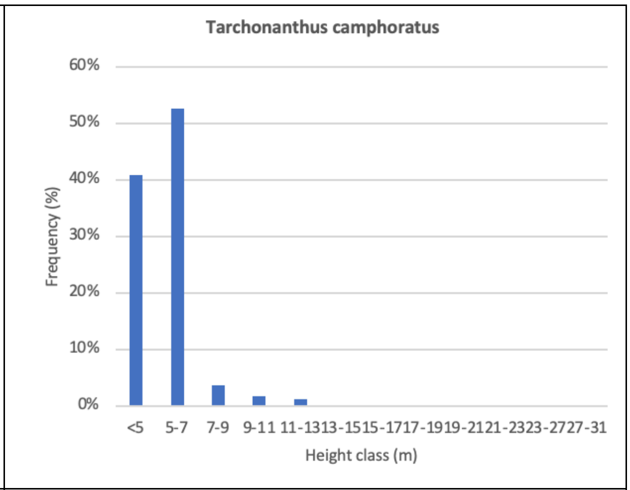

Cupressus lusitanica
Frequency (%)
30%
25%
20%
15%
10%
5%
0%
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead

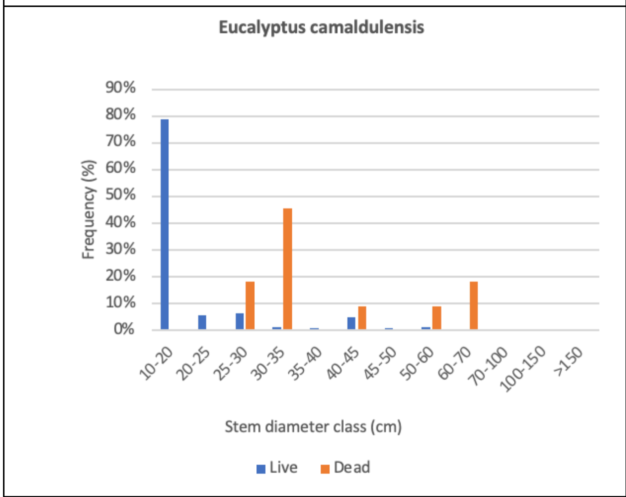

Cupressus lusitanica
Frequency (%)
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)


Eucalyptus grandis
Frequency (%)
70%
60%
50%
40%
30%
20%
10%
0%
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead


Eucalyptus grandis
Frequency (%)
25%
20%
15%
10%
5%
0%
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)


Tarchonanthus camphoratus
Frequency (%)
120%
100%
80%
60%
40%
20%
0%
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead


Tarchonanthus camphoratus
Frequency (%)
60%
50%
40%
30%
20%
10%
0%
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)


Eucalyptus camaldulensis
Frequency (%)
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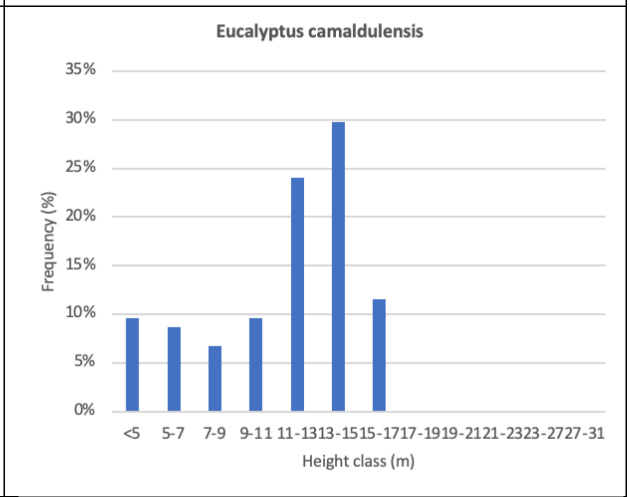
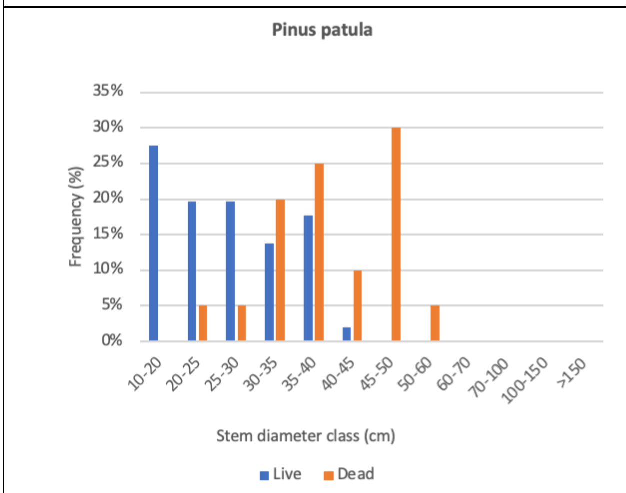
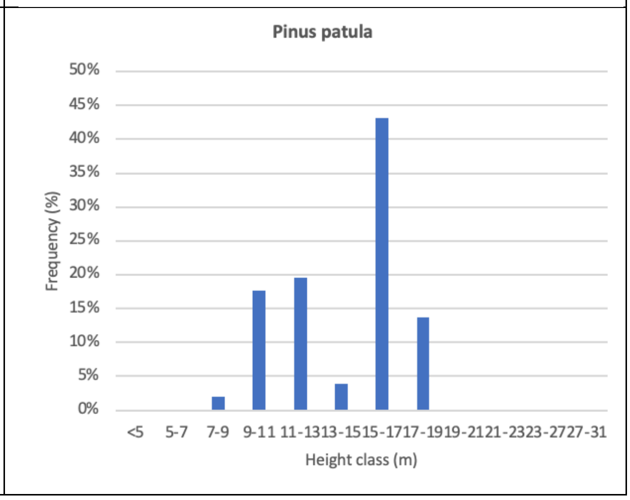
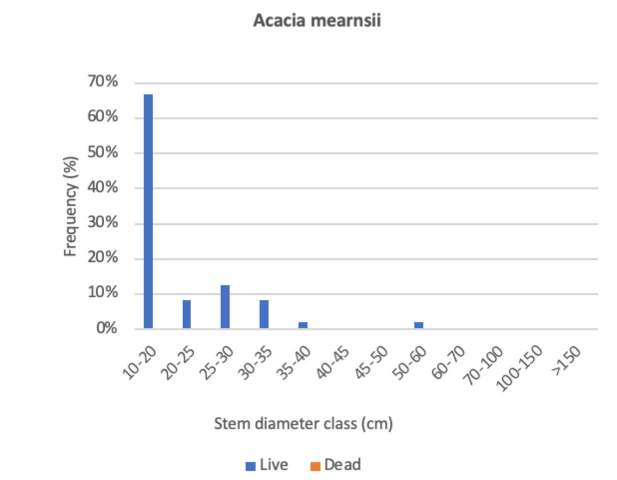
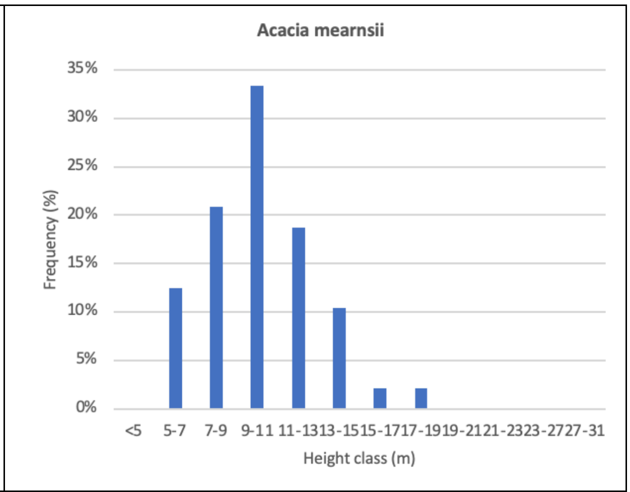
80%
70%
60%
50%
40%
30%
20%
10%
0%
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead

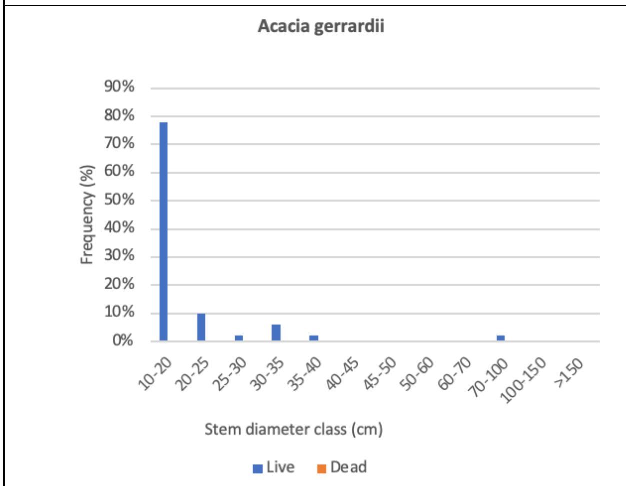

Eucalyptus camaldulensis
Frequency (%)
35%
30%
25%
20%
15%
10%
5%
0%
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)

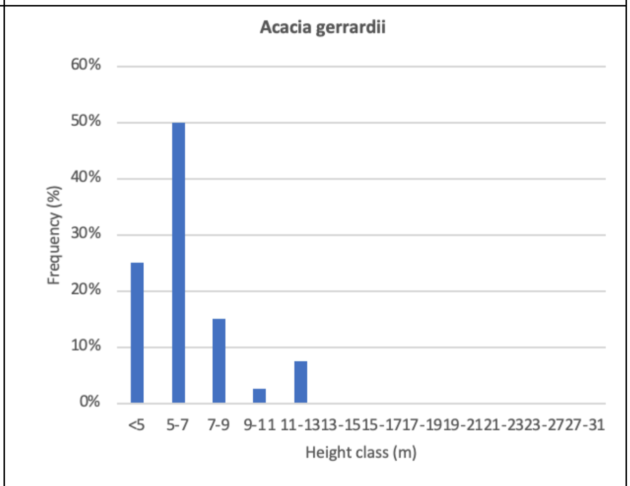

Pinus patula
Frequency (%)
35%
30%
25%
20%
15%
10%
5%
0%
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead

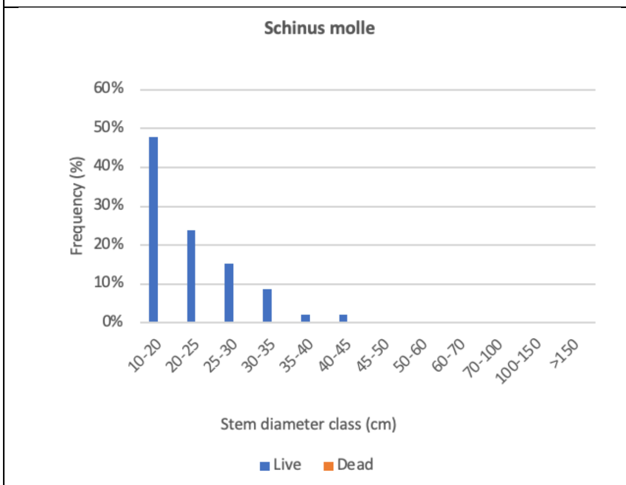

Pinus patula
Frequency (%)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)

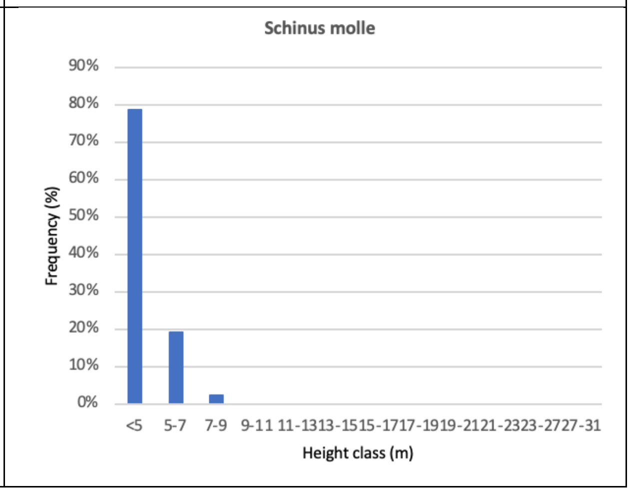

Acacia mearnsii
70%
60%
50%
40%
30%
20%
10%
0%
Frequency (%)
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead


Acacia mearnsii
35%
30%
25%
20%
15%
10%
5%
0%
Frequency (%)
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)


Acacia gerrardii
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency (%)
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead


Acacia gerrardii
60%
50%
40%
30%
20%
10%
0%
Frequency (%)
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)


Schinus molle
60%
50%
40%
30%
20%
10%
0%
Frequency (%)
10-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-100
100-150
>150
Stem diameter class (cm)
Live
Dead


Schinus molle
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency (%)
<5
5-7
7-9
9-11
11-13
13-15
15-17
17-19
19-21
21-23
23-27
27-31
Height class (m)

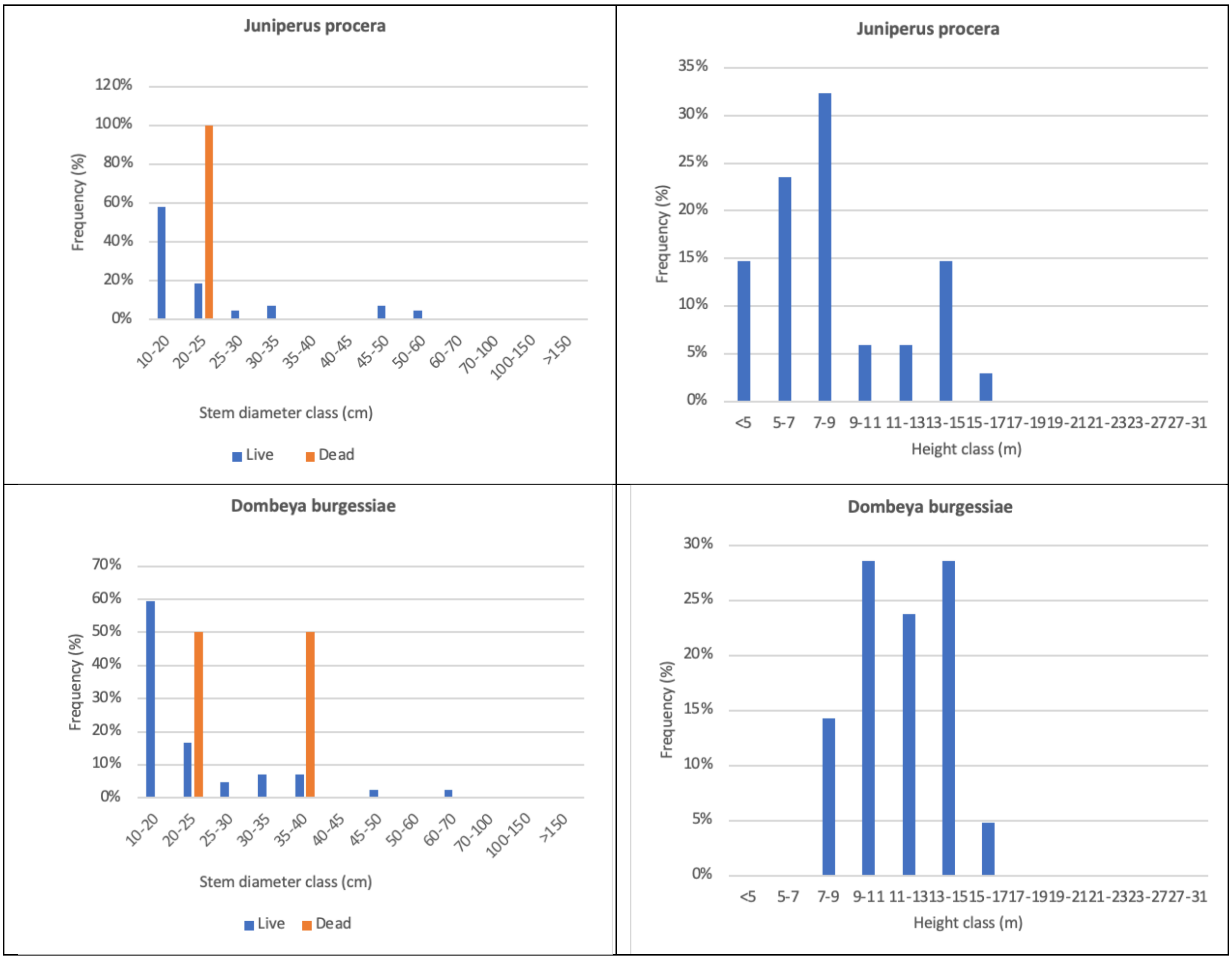


Figure 14: Stem diameter size class distributions of the most abundant tree species in the Nairobi to Mau Summit Local Assessment Area

5 DISCUSSION

5.1 CARBON

Several studies report on the carbon stocks in Kenya's different habitat types -

- One of the most recent reports came from a team using Earth Observation, they focused specifically on aboveground woody biomass carbon stock and found that in Kenyan forests this was on average 1.9 t C/ha annually and in wooded grasslands this was 0.6 t C/ha annually (Rodriguez-Veiga 2020).
- Pellikka & Heiskanen (2018) found that the highest aboveground biomass carbon stocks in Kenya were found in montane forests (mean values of 89.5 Mg C ha^{-1}) and exotic or plantation forests has much lower values (mean value of 29.4 Mg C ha^{-1}). Shrubland and cropland below 1220m a.s.l. provided the lowest aboveground biomass carbon stock in this study with an average of 2.6 Mg C ha^{-1} and 2.3 Mg C ha^{-1} respectively.
- Dabasso, Taddese & Hoag (2014) studied carbon stocks in northern Kenyan pastoral lands and found that across all landscape types the average carbon stock was 93.01 ±15.72 t C/ha. This figure is similar to other grazing areas across sub-Saharan Africa. Combining aboveground woody and herbaceous carbon, belowground woody and herbaceous carbon and soil carbon (to 30 cm) depth they found that shrubland had the highest total carbon at 115.7 ±15.00 t C/ha.
- Omoro, Starr & Pellikka (2013) found that overall aboveground biomass in indigenous forests (360± 148.1 Mg C ha^{-1}) was higher than the aboveground biomass in Cypress (158±66.6 Mg C ha^{-1}), Eucalyptus (221±143.2 Mg C ha^{-1}) and Pine (195±87.8 Mg C ha^{-1}) plantations in Kenya. They found similar results with belowground biomass.

- Oeba *et al.* (2016) studied the carbon content of *Eucalyptus saligna*, *Cupressus lusitanica* and *Pinus patula* plantations in three different areas in Kenya. They found that overall a *Eucalyptus saligna* plantation had the highest carbon content (247.9±44.4 Mg C ha^{-1}) and a *Cupressus lusitanica* plantation had the lowest carbon content (98.4±44.4 Mg C ha^{-1}). They also found that age was a significant factor in determining carbon content.
- Pfeifer *et al*. (2012) found that the mean aboveground carbon in East African closed woodlands is 103.1 t C/ha; in open woodland or savanna the aboveground carbon is 46.0 t C/ha; in bushland (scrubland) it is 61.6 t C/ha; and in grassland it is 17.9 t C/ha.
- Chamshama *et al*. (2004) estimated aboveground carbon in miombo woodland from 15 t C/ha to 22 t C/ha (calculated as 50% of biomass).
- Gibson & Joel (2017) found that the aboveground biomass in Kenya's indigenous South Nandi forest had a carbon density of 220±62 t C/ha, a figure equivalent to many of the planet's tropical forests.
- According to Kenya's forest reference level (FRL) submission to the UNFCCC the nation stores around 52,204,059 t CO_2 eq/year. Given the high level of land conversion in Kenya, the submission also included carbon stock changes as a result of land transformation. For example, conversion of forest to grassland changed carbon stock levels from 87.56 t CO_2/ha to 14.99 t CO_2/ha (UNFCCC, 2020).

Further afield, aboveground biomass (AGB) in tropical forests has been found to range between 152 and 596 t C/ha (Brown & Lugo 1984; Brown *et al*. 1989, 1996; Baccini *et al*. 2008; Djuikouo *et al*. 2010; Gautam & Pietsch 2012). Within the African tropical forests, aboveground biomass is significantly greater in Central African forests (429 t/ha) than East African (274 t/ha) and West African forests (305 t/ha). If these biomass values are converted to carbon values by applying a 50% carbon content for aboveground biomass, the mean aboveground carbon for East African forests would be 187 t C/ha (Lewis *et al*. 2013).

As summarized in Table 3 and Figure 4, the carbon pools for the different habitat classes showed substantial variation. Aboveground carbon ranged from 2.0 t C/ha (upland Acacia wooded grassland) to 170.2 t C/ha (Afromontane rainforest) and belowground carbon ranged from 1.0 t C/ha (upland acacia wooded grassland) to 56.7 t C/ha (Afromontane rainforest) across the nine habitat classes evaluated. Belowground carbon followed basically the same trend as aboveground carbon because the calculation of both above- and belowground carbon values are based on stem diameter and tree height data. The dead wood showed a range from 0.0 t C/ha (upland acacia wooded grassland and edaphic wooded grassland on drainage-impeded or seasonally flooded soils) to 33.4 t C/ha (Afromontane rainforest). Interestingly, those habitat classes with the highest aboveground carbon stocks (Afromontane rainforest and Afromontane bamboo) were actually dominated by tree species normally used in plantations in Kenya (i.e. *Pinus spp, Cupressus spp, Eucalyptus spp*). This shows that where indigenous forest may have been lost, plantation forests can still offer a carbon storage capacity, with perhaps lower levels of overall biodiversity. Those environments (such as halophytic vegetation and riverine wooded vegetation) dominated by indigenous species *(i.e Acacia xanthophloea*) stored less carbon than the ones dominated by exotic species. However, as grasses and forbs were not investigated in this study the carbon storage of these environments may have been underestimated.

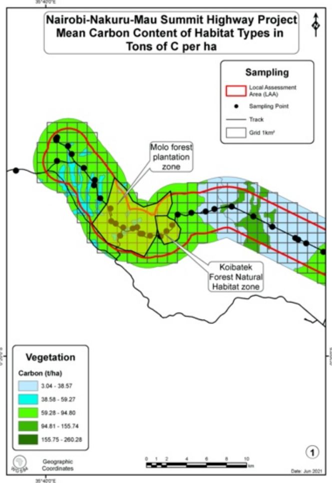
Soil carbon was also not determined in the current Nairobi to Mau Summit study. Some studies conducted in Kenya have reported that soil carbon pools can exceed the carbon contained in the aboveground vegetation and would therefore be an important component to measure in future investigations. For example, Tarus & Nadir (2020) carried out a study in the Eastern Mau Forest in Kenya, in close proximity to this report's study area, and found that soil carbon levels were highest in undisturbed natural forests (135.17 ± 35.99 Mg C/ha) and were lowest in plantations (116.51 ± 39.77 Mg C/ha). Dabasso, Taddese & Hoag (2014) provide a value of 78.93 ± 15.63 t C/ha in the soil in the woodland environments of pastoral northern Kenya. Omoro, Starr & Pellikkka (2013) found that in soil between 0 and 50 cm depth, the carbon level in indigenous forests (305 ± 58.1 Mg C ha^{-1}) was higher than Cypress (252±48.0 Mg C ha^{-1}), *Eucalyptus* (209±77.4 Mg C ha^{-1}) and Pine (168±72.5 Mg C ha^{-1}) plantations.

Figure 15 is a geographical illustration of the carbon density across the Local Assessment Area based on carbon figures reported per ha per habitat class. The combined carbon density in the nine habitat classes evaluated was classified into five classes. It is clear that the largest proportion of the Local Assessment Area has a carbon content of >3.04 to 38.57 t C/ha in the combined above-ground, below-ground and dead wood pools, this is the lowest carbon content category of the five classes created. Only a small proportion of the Local Assessment Area (predominantly afromontane forest areas) had the highest carbon content of >155.57 to 260.28 t C/ha.

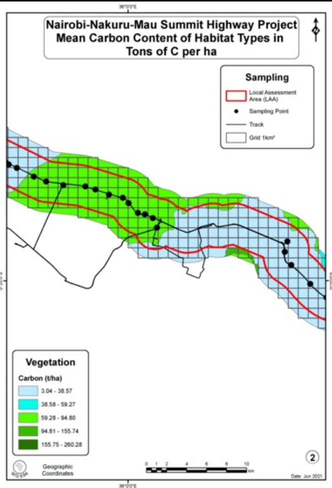
In Table 4, the carbon value is tentatively priced at USD 5.00 per T CO_2 equivalent as recommended in a recent review by the World Bank (2017)[1] for climate adaptation and climate mitigation carbon sequestration projects plans under REDD+. Values given must be considered as an *ab initio* cost per hectare in case of full habitat transformation in year 1 as a result of infrastructure development, which would represent integral release of CO_2 contents from the habitat in the atmosphere for the surface area defined as transformed by the project. This represents an emission value that Kenya cannot escape and has to compensate through its REDD+ schemes. As can be noted in table 4, despite this low financial value figure per tonne[2], Afromontane rainforest and Afromontane bamboo habitat class represent high value deforestation costs per ha (approx. 4,776.14 USD per ha for Afromontane rainforest and 3,337.08 USD per ha for Afromontane bamboo) should they be deforested. To this initial “deforestation loss” value, an annual fraction should be added to consider the recovery process that would be inhibited through complete land transformation and the potential gains in sequestration that will be negated per annum. Based on the IPCC (2006) documents, a standardised value for dry forests of Africa must be considered as 5.28 T CO_2 equivalent per annum for 1 – 20 years growth and 3.96 T CO_2 equivalent per annum beyond 20 years. This represents a minimum compensation cost of 26.4 USD per ha per year for the first 20 years and 19.8 USD per ha per year beyond 20 years (using the 5.00 USD per T CO_2 equivalent benchmark). This value must be considered as the lowest possible compensation benchmark for a full habitat transformation.

The above-mentioned value indications represent a simple “write off” estimate and do not consider the cost per ha over a “start-up” phase (typically 5 – 8 years) that would be required to setup a mitigation project under the REDD+ mechanism by the nationally competent and accredited authorities. Such values have a wide variability depending on the country’s goals. For REDD+ projects start-up phases, they have been reported to range between 22 USD per ha per year (proposal by Madagascar to the Green Carbon Fund in 2016), 99 USD per ha per year (proposal by Sri Lanka to Green Carbon Fund in 2017) to 104 USD per ha per year (proposal by Ivory Coast to Green Carbon Fund in 2017), while for the maintenance phase they typically represent 15 – 25 % of the start-up costs phase per ha per year. Typically, such values should be added to the compensation scheme to represent the investment requirement for Kenya to comply with their REDD+ commitments and “absorb” the emissions generated by the road expansion project should it lead to substantial forest or woodland clearance. In the current phase’s implementation of the REDD+ mechanism worldwide, REDD+ mitigation and adaptation projects/programmes are typically applied over vast application areas (10 – 25% of country land area, but in some instances national coverage also applies) in order to reach economies of scale when implementing. Contributions to such project’s propositions by the national authorities as a carbon offset by the project would be of interest to investigate.

1 Carbon Pricing Watch 2017 World Bank (http://www.climateactionprogramme.org/images/uploads/documents/Carbon_Pricing_Watch.pdf)
2 The above report also suggests that carbon pricing should be upwards of 10 USD per ton to be financially meaningful for the participating countries



a)



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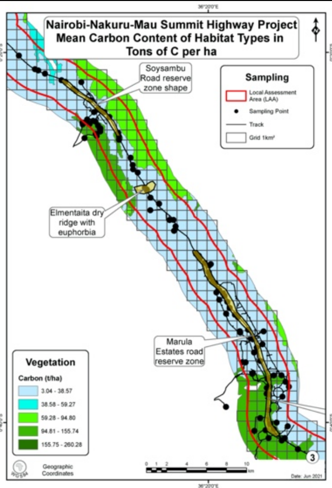

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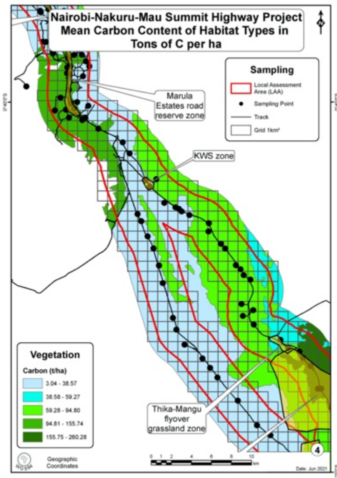

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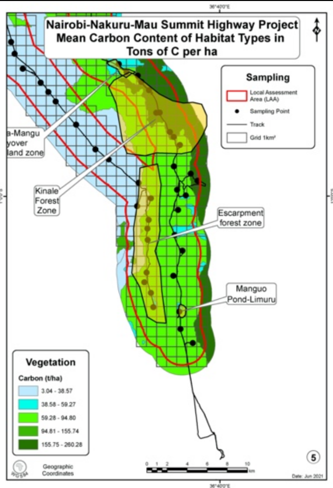

e)

Figure 15: Carbon content in the combined above-ground, below-ground and dead wood pools in the Nairobi to Mau Summit Local Assessment Area, Kenya.

The World Bank (2017) considers that it is unusual for carbon offset projects to be successful at the 5.00 USD per tonne CO_2 equivalent price and that prices closer to USD 10.00 per tonne are more typical, however, under the UNFCCC context for REDD+, the pricing at 5.00 USD represents a by default standardised value that has been used by the international agencies and the Green Carbon Fund to measure and compare climate mitigation and adaptation project return potential when carbon based investments are made. Recent average prices for forest and land-use offsets in the voluntary market[3] are USD 5.1 per tonne, with REDD+ credits averaging USD 4.2 per T CO_2 equivalent, afforestation/reforestation USD 8.1 per T CO_2 equivalent and Improved Forest Management USD 9.5 per T CO_2 equivalent. In the context of the climate change discussions held at the various Conference of the Parties since 2015, it would be a safe assumption to use 10.00 USD per T CO_2 equivalent as the likely future real value.

5.2 SIZE CLASS DISTRIBUTION OF SPECIES

Overall, the stem diameter size class distributions of the different associations showed inverse J-shaped curves indicating generally healthy populations. In contrast, the height class distribution of most associations did not show the largest numbers of individuals in the smallest size classes. Many habitat classes (such the evergreen and semi-evergreen bushland and thicket and the riverine wooded vegetation classes) showed the majority of trees measured between 5 and 7 m in height. In the habitat classes with the most carbon content (Afromontane bamboo and Afromontane rainforest) the majority of trees measured between 15 and 17 m in height. Several factors could be contributing towards the lack of agreement between the diameter and height class distributions:

- Firstly, it should be kept in mind that the cut-off diameter for inclusion in the survey was 10 cm. In general, tree development follows a pattern of rapid increase in plant height at low diameter breast height (Ogbazghi *et al.* 2006) with a gradual decrease in the rate of height growth at larger stem diameters. It could be that most trees with a stem diameter of 10 cm would already be taller than the smallest height classes illustrated in Figure 14. Individuals with a diameter of <10 cm could therefore be the ones that contribute most to these lower height classes and these individuals were not measured in this study.
- Secondly, height growth could be delayed as a result of human use, such as plantation development. The planting technique followed in the areas surveyed may encourage upwards growth and the height of trees may be controlled through cropping at particular heights. This would, however, imply that human use was not having a similar effect on the stem diameter.

5.3 PLANTATIONS

Plantation forestry has a long history in Kenya and has been integral for the provision of timber for infrastructure, fuel wood and significant employment opportunities. The development of plantations really began in Kenya in the 1960s with the establishment of *Eucalyptus* (*Eucalyptus saligna*), Cypress (*Cupressus lusitanica*) and Pine (*Pinus spp*) plantations. Indigenous forest was cleared to make way for plantations; however, these plantations were considered to act in a buffer capacity to protect remaining patches of indigenous forest. Very few plantations have been used by local communities and have rather supported national scale projects (Omoro, Starr & Pellikka, 2013).

Many studies have found that despite their maintenance of overall forest cover, plantations do not offer the same carbon storage capacity as indigenous forests. Omoro, Starr & Pellikka (2013) found that in Kenya, above and belowground biomass overall was higher in indigenous forests (450±185.1 Mg C ha^{-1}) than in Cypress (197±84.3 Mg C ha^{-1}), *Eucalyptus* (292±189.5 Mg C ha^{-1}) or Pine (242±108.8 Mg C ha^{-1}) plantations. Others have suggested the opposite, indicating that based on the predominance of fast-growing species, plantations can sequester more carbon than naturally occurring forests (Oeba et al., 2016).

The carbon storage capacity of plantations is dependent on multiple factors, including the species grown and the location, age and maintenance of the plantation. Oeba et al (2016) found that, when compared to Cypress and Pine plantations, *Eucalyptus* plantations tended to store more carbon in a shorter amount of time based on the rapid growth of Eucalypts. They also found that plantations with lower stand densities and thus lower competition had higher carbon stocks. Age has also been shown to play a statistically significant role in plantation-based carbon storage, generally

3 State of the Voluntary Carbon Market 2017 (http://www.forest-trends.org/documents/files/doc_5591.pdf

the older the plantation, the more carbon it stores, yet this is relatively species specific. In addition, the location of a plantation (and hence the weather patterns which affect it) influence carbon storage capacity; Paul et al (2008) found that higher levels of rainfall resulted in greater carbon storage capacity.

The Nairobi to Mau Summit Local Assessment Area a has great variation in altitude, and thus weather conditions, particularly rainfall. In this study, the Afromontane rainforest habitat class, which was located at the highest altitude of the Local Assessment Area, had the largest carbon stocks. This habitat class was dominated by Cypress species, suggesting the presence of plantations in this habitat class. Areas with more natural habitat such as the riverine wooded vegetation class contained a smaller carbon stock. While there are still patches of natural vegetation in the Afromontane rainforest habitat class which contribute to the carbon storage capacity of this habitat class overall, the role of plantations cannot be ignored. Plantation establishment can significantly reduce the overall biodiversity of an area, however when viewed simply from a carbon storage capacity standpoint, plantations offer huge capacity to mitigate climate change and sequester harmful gases, they can also play a key role in a nation's REDD+ target achievement. In Kenya specifically, a nation known for its low forest cover, afforestation or reforestation in the form of plantations can offer a valuable method of increasing the country's carbon storage capacity.

5.4 DEGRADATION/DEFORESTATION

The landscape of the Nairobi to Mau Summit Local Assessment Area is heavily impacted by humans and it is clear that the majority of the area has been transformed away from natural landscapes towards those used for agriculture and industry. The long history of plantation establishment in the area has caused significant deforestation. However, it could be argued that despite the deforestation in the study area the resultant land use still provides a forest cover and thus offers a carbon store and a habitat for biodiversity, something which would not be offered through the urbanisation of an area. Nevertheless, the development of plantations creates a source of employment which thus draws in people and encourages the conversion of land by the wider community. Communities may practice deforestation to make way for livestock grazing lands and to harvest fuelwood and charcoal (Anonymous, 2016). Practices such as this often bring about forest degradation which will likely result in entire deforestation if left unchecked. Based on inaccessibility it does appear that some areas of the study area have remained in their natural state, however these are limited to the mountanous fringes of the Nairobi to Mau Summit region. Nevertheless, this can provide a bastion of biodiversity and, as multiple studies have shown, support the vegetation with the highest carbon storage capacity (Omoro, Starr & Pellikka 2013; Pellikka & Heiskanen 2018).

5.5 METHODOLOGICAL UNCERTAINTIES

There are inevitably sources of error that occur when determining carbon stocks and therefore, the Intergovernmental Panel on Climate Change (Watson *et al*. 2000; Penman et al. 2003) require errors and uncertainties to be documented when conducting carbon accounting. The carbon stock estimates for the Nairobi to Mau Summit Local Assessment Area provided (Appendix B) in this report are subject to a number of uncertainties. However, the results are on a higher level than calculations based on global default values and therefore, should be more accurate (Penman *et al*. 2003). The section below outlines some of the shortcomings of the study and suggests ways in which improvements can be made (see also Chave *et al*. 2004).

Sampling and extrapolation errors are generally the largest source of error. The following are some examples:

- Limited sampling within some habitat classes was done, resulting in a low representativeness if the vegetation is relatively heterogeneous.
- Ideally, the sample size (number of stands sampled within each unit) should be statistically determined to ensure a targeted precision level. However, it was not the purpose of this preliminary inventory to sample within 95% confidence limits. The standard error of the mean of the combined above and belowground carbon was between 10% and 20% for all associations. For biological data, a standard error of 10% of the mean has been regarded as acceptable (Green 1979), whereas Elliot (1977) suggested 20% as acceptable.
- Ideally, the size of the sampling plots should also be established statistically.

The most important model and measurement errors include:

- The selection of the allometric equations for the indigenous vegetation. Because species-specific or area specific equations were not available the selection had to be based on what was available in the literature.
- The selected allometric equations were applied to all stem diameter sizes, regardless of whether they fell within the range for which they were originally developed. However, almost all individuals measured in the study site had diameters within the specified range.
- The litter and soil carbon pools were not sampled.
- Only individuals with a diameter at breast height (DBH) ≥10 cm were recorded.
- Care was taken to limit any measurement errors.

6 CONCLUSIONS

The carbon contained in the vegetation in the Nairobi to Mau Summit Local Assessment Area a compares well with the carbon content of similar savanna and woodland types in East Africa. The highest carbon values were found in the Afromontane rainforests which are covered by both indigenous forest and plantations. The lowest values were found in the relatively unforested upland acacia wooded grassland. The area of high carbon content is covered by Afromontane rainforest and is limited to the very eastern fringes of the Local Assessment Area. The majority of the land in the Nairobi to Mau Summit Local Assessment Area has a carbon content of between >3.04 – 38.57 t C/ha, this low level of storage is likely explained by the high level of land transformation in the s Local Assessment Area and the conversion of natural landscapes to urbanised areas or agricultural sites.

The diameter size class distribution for most associations showed inverse J-shaped curves, indicating healthy populations. The height class distributions, however, revealed lower numbers in the smallest height classes. These results are likely influenced by the anthropogenic control on exotic tree species introduced through plantation forestry as many of the most dominant tree species in the habitats have been introduced. The carbon storage capacity of plantation tree species such as Pine, Eucalyptus and Cypress is dynamic, however certainly offers more storage potential than complete transformation of land towards urbanised areas. Thus, the specific role of plantations in storing carbon in the Nairobi to Mau Summit Local Assessment Area warrants further investigation.

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8 Appendix A:

Definitions for carbon pools in the Agriculture, Forestry and Other Land Use (AFOLU) sector (Eggleston *et al*. 2006)

Pool		Description
Biomass	Aboveground	All biomass in living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds and foliage.
	Belowground	All biomass of live roots. Fine roots of less than 2 mm diameter are often excluded because often these cannot be distinguished from soil organic matter or litter.
Dead organic matter	Dead wood (Coarse woody debris)	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 100 mm in diameter (or a diameter specified by the country). In many countries, a cross-sectional diameter >25 mm rather than 100 mm is applied (McKenzie et al. 2000).
	Litter	Includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood, lying dead, in various states of decomposition above or within the mineral or organic soil. This includes the litter layer as usually defined in soil typologies. Live fine roots above the mineral or organic soil (of less than the minimum diameter limit chosen for belowground biomass) are included in litter where they cannot be distinguished from it.
Soil	Soil organic matter	Includes organic carbon in mineral soils to a specified depth chosen by the country. Live and dead fine roots and dead organic matter within the soil that are less than the minimum diameter limit for roots and dead organic matter, are included with soil organic matter where they cannot be distinguished from it. The default soil depth is 300 mm.

9 Appendix B:

Carbon with standard error (SE) contained in three pools in the various plant associations at the Nairobi to Mau Summit study area, Kenya.

Habitat types	Mean for live AGB CO_2 mass per ha (tonnes)	Standard error (SE) for AGB	Mean for live BGB CO_2 mass per ha (tonnes)	Standard error (SE) for BGB	Mean for dead tree CO_2 mass per ha in tonnes	Standard error (SE for dead trees
Afromontane bamboo	478.0	79.3	169.4	28.4	20.0	8.5
Afromontane rainforest	624.6		208.0		122.7	
Afromontane undifferentiated forest	188.8	38.0	64.8	11.9	4.3	1.4
Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	137.7		45.7		0.0	
Evergreen and semi-evergreen bushland and thicket	86.9	19.9	27.3	4.5	0.7	0.3
Halophytic vegetation	146.7	99.9	49.5	31.4	24.0	24.0
Riverine wooded vegetation	333.9	72.4	93.4	17.4	18.5	11.3
Upland Acacia wooded grassland	7.5		3.7		0.0	
Water bodies	265.9		91.9		85.2	

APPENDIX

6-16 *BIODIVERSITY BASELINE INVESTIGATION – AVIFAUNA*

Nairobi-Nakuru-Mau Summit Highway Project
Biodiversity baseline studies for the ESIA
Republic of Kenya

BIODIVERSITY BASELINE INVESTIGATION
AVIFAUNA
FINAL REPORT

Compiled by:
Lukas Niemand, *Pr. Sci. Nat*

July 2021

Document history

Version	**Reviewed by**	**Requests noted**
Draft V1	Jerome Gaugris, *Pri. Sci. Nat.*	
Draft V2	WSP – Maya Brennan Jacot	
FINAL version	Lukas Niemand, *Pri.Sci.Nat.* Phoebe Mottram, *Cand.Sci.Nat* Jerome Gaugris, *Pri.Sci.Nat.*	

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Nairobi-Nakuru-Mau Summit Highway Project Expansion & Upgrade Biodiversity baseline studies for the ESIA Republic of Kenya

BIODIVERSITY BASELINE INVESTIGATION AVIFAUNA

1. CONTEXT

WSP Canada has been commissioned by Rift Valley Highway Limited (RVHL) to complete the Environmental and Social Impact Assessment (ESIA) for the Nairobi-Nakuru-Mau Summit Highway Project. The ESIA is undertaken in order to anticipate and identify adverse environmental and social risks and develop robust mitigation measures through the application of mitigation hierarchy. As part of the WSP Canada consortium in the proposal made to RVHL, Flora Fauna & Man Ecological Services Ltd (FFMES) has been tasked to undertake the biodiversity surveys along the proposed road alignment. A first round of work, covering the dry season was undertaken in February 2021, from 17 to 26 February (10 days of field work). Another round of work, covering the wet season, was undertaken from 13 to 25 April 2021 (12 days of field work).The work was undertaken by a multidisciplinary team of experts spanning the following disciplines

- Vegetation, including woody biomass;
- Mammals (including small terrestrial mammals);
- Avifauna;
- Herpetofauna (Reptiles & Amphibians);
- Freshwater ecology.

The present document provides an outline of the work undertaken with respect to the following discipline:

- Avifauna;

This work was undertaken by the following team member:

- Lukas Niemand
  - BSc (Zoology), BSc (Hons), MSc (Restoration Ecology)
  - SACNASP (Registration Number: 400095/06) in the following fields of practice:
    - Ecological Science
    - Zoological Science
  - Number of years of experience: 15 years
  - Number of publications: 3
  - Experience in the country or region:
    - Ethiopia
    - Tanzania
    - Malawi
    - Mozambique

2. INTRODUCTION

FLORA FAUNA & MAN, Ecological Services Ltd. was commissioned to undertake an avifaunal specialist study for the proposed Nairobi-Nakuru-Mau Summit Highway Project in the Republic of Kenya. The project plans the duelling of the A8 Rironi to Mau Summit highway and the strengthening of the A8 South Rironi to Naivasha road (Old Naivasha Road). The existing Rironi to Mau Summit highway is part of the A8 Highway and Northern Corridor that links the Port of Mombasa via Nairobi to Kampala up to Malaba at the Uganda border. It is one of the most important and busiest transport corridors between East and Central African countries, thereby linking the Port of Mombasa via Kenya with landlocked countries such as Uganda, Rwanda, Burundi, South Sudan and the Democratic Republic of Congo.

The objectives of the avifauna specialist study were to: (a) describe the bird associations within the respective habitat units located along the highway (within a 2 km buffer area on either side of the road); (b) provide an inventory of bird species occurring in the various habitat units along the highway; (c) provide an assessment of prominent functional guilds; and (d) provide an indication on the occurrence of species of concern (e.g. threatened and near threatened species; according to IUCN, 2021).

The avifauna of Kenya is well documented, and the country is globally well known for its wildlife, national parks and geological formations, thereby attracting not only vast numbers of tourists each year to the country, but also amateur and citizen ornithologists ("bird-watchers"), who are in some way contributing towards the documentation of the country's avifauna.

This report aims to provide a baseline study on the avifaunal community and bird species diversity along the proposed survey area. The information can then be used to update extant bird distribution ranges ; highlight important areas or zones with high bird richness or endemism; assist with the identification of biodiversity offset areas (if relevant); and provide "indicator" species of ecological succession to be monitored during rehabilitation.

2.1. Ornithological Importance: Kenya

Kenya is topographically diverse with glaciated mountains, volcanoes, the Rift Valley, flat desert landscapes in the north, including large endorheic or soda lakes and coral reefs and islets in the east. It consists of a coastal plain that gives way to an inland plateau that rises to the central highlands due to recent volcanic activity and the formation of the rift valley. The country has one of the richest avifauna in Africa with approximately 1, 162 bird species recorded to date (Lepage, 2021), of which 11 species are endemic to East Africa (shared with Tanzania and Uganda). Approximately 170 bird species are Palearctic migrants, with another 60 species being Afrotropical migrants (Bennun and Njoroge, 1999). Being a country that is topographically diverse, the resultant natural vegetation is also extremely diverse with Afro-alpine moorlands on Mount Kenya, the Aberdare Mountains, the Cheranganis and at Mount Elgon, and upland grassland (e.g. the Kinangop and Mau Narok-Molo grasslands) above c. 3000 m with highland moist forest between 1500 to 3000 m. Coastal forest and Guinea-Congolian montane forest are also respectively found in eastern and western Kenya, along with riverine forests. It is not surprising that Kenya has over 335 bird species confined to forests. Of these, 230 are entirely dependent on forests habitat, and 110 species are specialists of intact untransformed forest habitat. Furthermore, the Great Rift Valley represents a major migration passage for Palearctic birds, while the vast number of endorheic lakes within the Rift Valley basin attracts significant numbers of waterbirds, especially flamingos.

Approximately 89 bird species recorded from Kenya are threatened (c. six species are Critically Endangered, 19 species are Endangered, 23 species are Vulnerable), near threatened (c. 39 species) and two are also Data Deficient (IUCN, 2021). Of these, 22 species are Palearctic migrants (IUCN, 2021). From a conservation perspective, the country also has five Endemic Bird Areas[1] (c. Tanzania-Malawi mountains, Serengeti plains, Kenyan mountains, East African coastal forests and the Jubba and Shabeelle valleys) and three Secondary Areas[2] (c. the Kakamega and Nandi forests, the North Kenyan short-grass plains and Mount Kulal) which

[1] An area that supports two of more species of restricted range, and thus located in an area where the entire global breeding range of the species is estimated to be less than 50, 000km2 (Fishpool & Evans, 2001).

[2] An area with one or more restricted range species but does not qualify as an Endemic Bird Area since fewer than two species are confined to it (Fishpool & Evans, 2001).

cumulatively provide habitat for 30 range-restricted bird taxa (Bennun and Njoroge, 1999; Stevenson and Fawnshawe, 2020). Of these, only the Kenyan mountains are located within the survey area. The country also spans six major biomes, each with its own distinct avifaunal association restricted to it: Afrotropical Highlands biome (an area that is represented by the central highlands with approximately 70 species), Somali-Masai biome (94 species restricted to an east-African woodland zone which occurs from northern Tanzania into the Horn of Africa), East African Coast biome (with approximately 30 species confined to the east coast littoral), the Lake Victoria Basin (with nine species confined to the Lake Victoria catchment), and two outliers of Sudan-Guinea savanna biome (13 species restricted to a woodland zone that occurs stretches further into West Africa) and the Guinea-Congo forest biome (43 species that are primarily confined to lowland forest) (Bennun and Njoroge, 1999). The survey area is primarily located within the Afrotropical Highlands Biome, with some overlap in lowland areas with the Somali-Masai and Lake Victoria Basin Biomes.

2.2. Ornithological Importance: Local Context

The survey area is topographically diverse, especially since it traverses the Rift Valley and consists of eight discrete habitat units that range from Afromontane forests to woodland and varius wetland-associated habitat units characterised by endorheic lakes, rivers and streams, halophytic vegetation and edaphic grassland associated with upland wetlands and seeps. The area provides habitat for many forest and grassland bird species that are restricted to the Afrotropical Highlands biome and some of these are characteristic of the Kenyan mountains Endemic Area (e.g. Hunter's Cisticola *Cisticola hunteri* and Kikuyu White-eye *Zosterops kikuyuensis*). The A8 highway alignment is located in close proximity to the Kinangop grasslands, which used to be a key locality for the endemic and globally endangered Sharpe's Longclaw (*Macronyx sharpei*). The Rift Valley is considered as a major flyway for waterbirds and Palearctic migrants, notably birds of prey during the spring and autumn passage. The project is also located in close proximity to large endorheic lakes, which are all important congregatory habitat for waterbird species and seasonal feeding stations for large numbers of Lesser Flamingo (*Phoeniconaias minor*).

3. STUDY AREA

3.1. Location and general description

The survey area is located south of the Equator in the south-central part of Kenya between the capital of Nairobi in the south-east and Eldoret in the north-west. The project covers approximately 177 km of road from the junction between the Old Naivasha and Limuru Roads near Nairobi in the south to Mau summit in the north (Figure 1). The project also involves the survey of habitat units along the proposed strengthening of the A8 South Highway (Old Naivasha Road). This road, of approximately 57.4 km in length and is located between the junction of the Old Naivasha Road with Limuru Road in the south and the Naivasha town in the north (Figure 1).

The survey area corresponds to the Project's Biodiversity Local Assessment Area, which includes a 2 km buffer on either side of the roads. It is situated within the southern Rift Valley Province while also traversing near a number of protected areas and conservancies such as the Kinale forest block (which includes the Gatamaiyo Forest Nature Reserve), the Longonot, Lake Naivasha and Lake Nakuru National Parks and conservancies such as Marula Estates, the Kigio Wildlife Conservancy and the Soysambu Conservancy at Lake Elmenteita. The survey area incorporates tremendous topographical diversity which includes the Great Rift Valley and its associated escarpments and volcanoes. It also incorporates a chain of endorheic lakes (Lakes Naivasha, Elmenteita and Nakuru) located within several basins of internal drainage in the Rift Valley. The northern and southern parts overlap with the central highlands and encompass a number of highland moist forest patches and upland grassland.

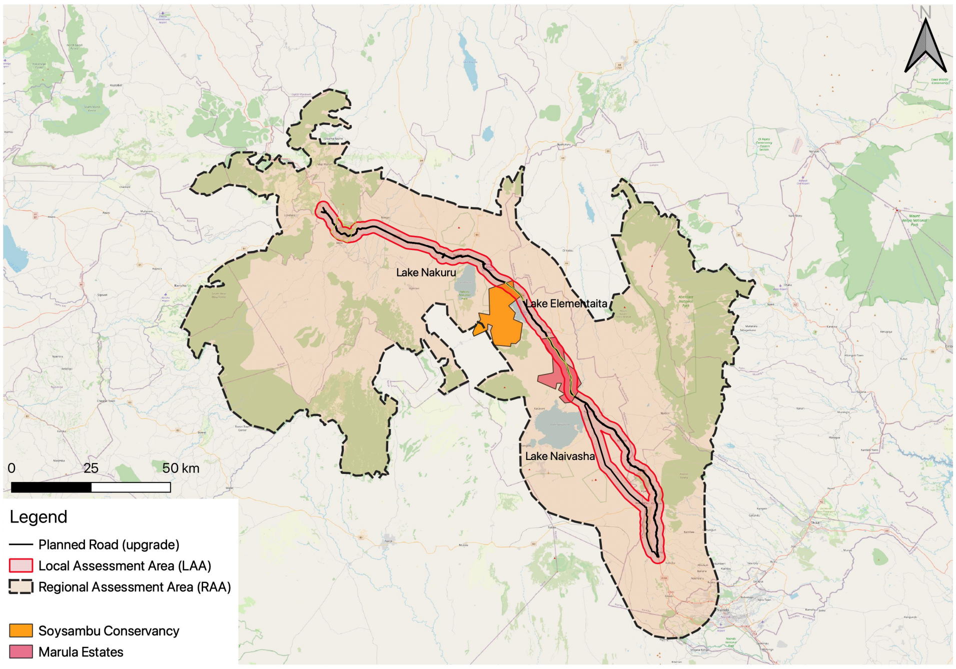


Figure 1 Location of the Nairobi-Nakuru-Mau Summit Highway Project area in Kenya. The Local Assessment Area corresponds to a 2 km buffer area on either side of the A8 Highway. The Regional Assessment Area to a 15 km buffer area on either side of the A8 Highway.

3.2. Broad-scale habitat description

The survey area is characterised by eight broad-scale habitat classes according to the VECEA[3] potential natural vegetation map for Eastern Africa (van Breugel et al, 2015) located within a 2 km buffer area on either side of the road. Each of these units differs from each other in floristic composition, floristic structure and topography (**Error! Reference source not found.** and

[3] Vegetation and Climate change in East Africa project.

Table 1). The majority of these floristic associations and habitats are characteristic of the Afrotropical Highlands Biome, which explains the high prevalence of forest bird species restricted to the Afrotropical Highlands. However, many of the units are invariably associated with anthropogenic activities, which range from settlements and urban areas to cultivation and pastoralism, thereby rendering large parts of these habitat units as degraded and of secondary succession (e.g. perturbed), while certain parts show a high prevalence of alien plant infestation. Some of the habitat types are classified as azonal habitat, which refer mainly to areas of lentic (stationary or relatively still) surface water (e.g. artificial dams, ponds or pans). These often provide ephemeral foraging habitat for waterbird taxa. Appendix 2 provides examples of the floristic structure of each broad-scale habitat unit as observed on the Local Assessment Area.

Table 1: The broad-scale habitat types corresponding to the survey area that was surveyed during the avifaunal investigation (equivalent units as specified in the habitat studies are indicated). Please note that abbreviations used here generated in the field and were used for analysis - these differ from the abbreviations used by the VECEA project by van Breugel et al, (2015).

Broad habitat class	Ecological condition	VECEA Description
1. Afromontane Undifferentiated Forest (AUF)	Mostly modified and secondary.	Undifferentiated Afromontane forest is usually shorter than Afromontane rain forest and despite some floristic overlap is of distinctive composition, often with a dominance of *Juniperus procera* or *Hagenia abyssinica*. Mostly degraded and of secondary succession where it occurs as remnant patches along perennial stream and rivers between 1700 and 2900 m above sea level. Large tracts of this forest habitat have been converted to plantations with some areas cleared under the 'shamba' system. The typical bird association consists of many forest-dependant species, including a high number of species restricted to the Afrotropical Highlands Biome. Areas of special interest that form part of the undifferentiated Afromontane forest includes the Escarpment forests (along the A8 South Highway on the southern part of the survey area) and the Koibatek forest patch and Molo forest-plantation zone in the north of the survey area. The Manguo Pond just beyond the Limuru Flyover is embedded within this unit, which is an important foraging and breeding wetland for waterbird and congregatory bird species.
2. Afromontane Rainforest (AfR)	Some sections contain intact forest, especially in the south, while most sections in close proximity to the A8 highway are degraded.	Afromontane rain forest is similar in structure and physiognomy to Guinea-Congolian lowland rain forest with an upper stratum of 25 to 45 tall trees that are heavy branched and wide-spreading; a middle tree stratum of 14 to 30 m tall, with narrow crowns but do not form a dense canopy; a lower tree stratum of 6 to 15 m tall and forming a dense canopy, followed by a shrub layer of 3 to 6 m tall but poorly differentiated from the lower tree layer. The Afromontane rain forest differs from the Guinea-Congolian rain forest in the occurrence of tree ferns *Cyathea* spp. and *Podocarpus/Afrocarpus* spp. Good examples of this forest unit is represented in the Kinale and Gatamaiyo Forest east of Kimende town. This habitat unit provides habitat for many forest-dependant bird species, including many species restricted to the Afromontane Highlands forest Biome. It forms an integral part of the Kenyan mountain Endemic Bird Area.
3. Afromontane Bamboo (AfmB)	Highly fragmented and mostly of secondary conditions.	Afromontane bamboo forest is dominated by *Yushania alpina* (*Sinarundinaria/Arundinaria*) which occurs on most of the high mountains at altitudes of 2380 to 3000 m above sea level. Also often present as an understory in *Juniperus* forest. It occurs mainly in the southern highland areas of the survey area, where it is highly fragmented. Some parts have been converted to cultivation and plantations.
4. Upper Acacia Wooded Grassland (UAWG)	Highly fragmented with large sections invaded by alien plant species.	This unit is scattered along the east-facing slopes of the Rift Valley as an "alternative steady state" of Evergreen and semi-evergreen bushland and thicket (ESEBT). When untransformed, it conforms to a moist and tall savannoid grassland with tall *Acacia xanthophloea, A. abyssinica* and *A. drepanolobium.*
5. Evergreen and Semi evergreen Bushland and Thicket (ESEBT)	Variable, tall and intact woodland stands mainly confined to conservancies. Large parts of secondary condition and converted pioneer thicket also occur.	This vegetation type is prominent on the survey area and occurs on drier slopes of mountains and upland areas, often forming an ecotone between Afromontane forest and deciduous bushland. When untransformed, this unit is characterised by tall *Acacia xanthophloea* woodland or *Tarchonanthus* woodland (leleshwa). Good examples of this unit are conserved within the Soysambu and Kigio conservancies and the Marula Estates. Large parts have been converted to pastures and cultivation which resulted in open short shrubland dominated by secondary grasses and *Solanum* spp.

Broad habitat class	Ecological condition	VECEA Description
6. Edaphic wooded grassland (EWG)	Variable, mainly secondary owing to intense grazing by livestock.	This vegetation type is drainage-impeded or found on seasonally flooded soils. Where the estimated tree cover is > 10%, the vegetation is classified as edaphic woody grasslands while the remainder is classified as edaphic grasslands. It is often associated with hillslope seeps or unchannelled valley-bottom seeps, which attract waterbirds and grassland-associated bird species.
7. Riverine wooded vegetation (RWV)	Mainly intact along larger rivers and in conservancies.	This unit occurs as a narrow band of tall woodland along major drainage systems, especially along the Malewa, Gilgil and Molo Rivers and some of their tributaries. Typical tree species include *Diospyros mespiliformis, Ficus sycomorus, Syzygium guineense* and *Trichilia emetica*. However, many species from adjacent vegetation types also occur.
8. Halophytic vegetation (HalV)	Mainly natural although highly dynamic and subject to drastic changes in inundation levels and salinity.	This unit is restricted to the shoreline of endorheic lake systems, notably Lakes Nakuru, Elmenteita and Naivasha. It represents a small group of plants that can grow on saline soils typically found along the Rift Valley lake systems. Characteristic species found around these lakes are *Cyperus laevigatus, Sporobolus spicatus* and *Sueda monoica*. When inundated, this unit provides critical important foraging habitat for large numbers of waterbird, shorebirds and congregatory bird species, especially flamingos.

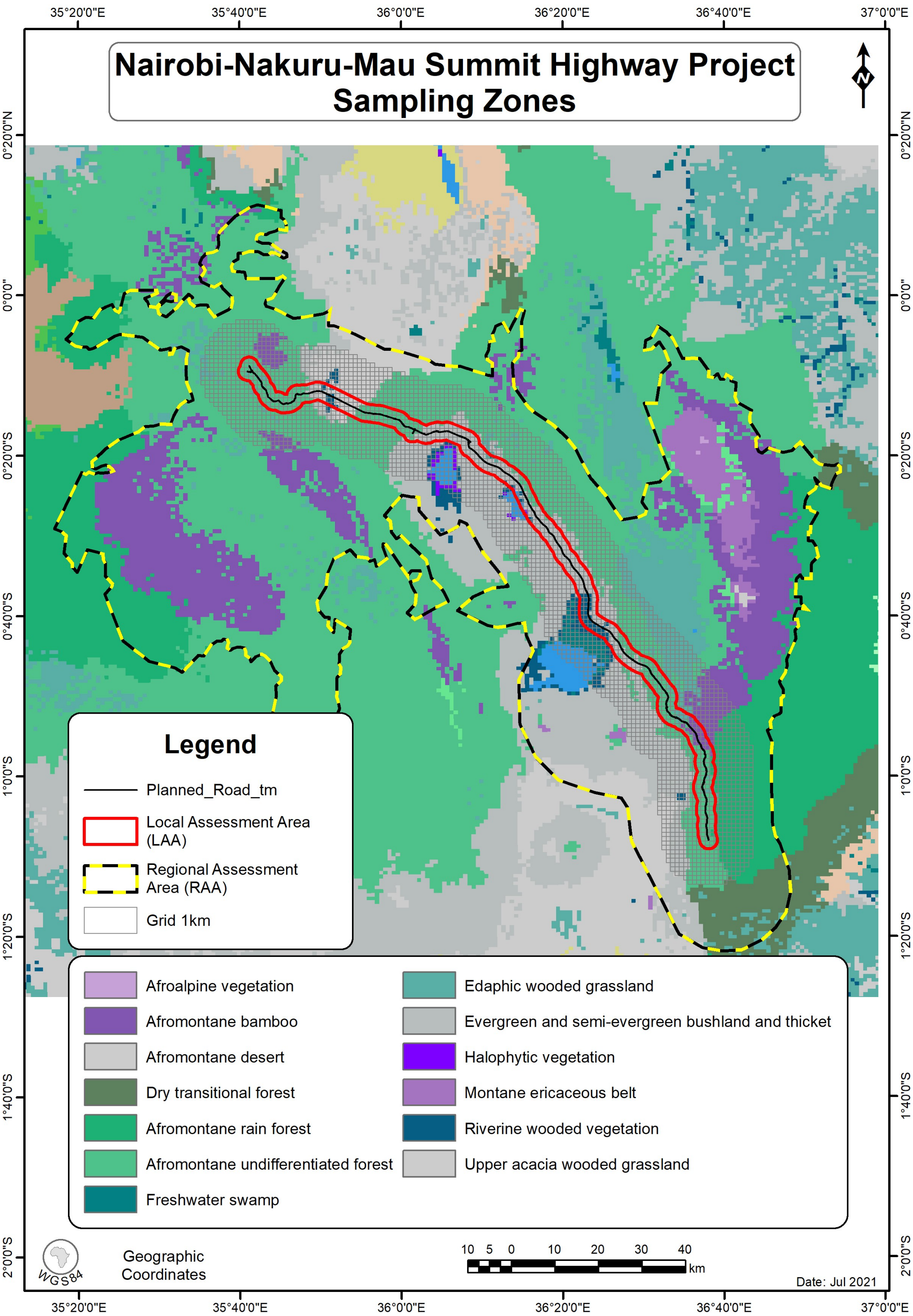


Figure 2: The spatial location of the broad-scale habitat types on the Local Assessment Area (located within a 2km survey/buffer area on either side of the highway) and the Regional Assessment Area (located within a 15km survey/buffer area on either side of the highway).

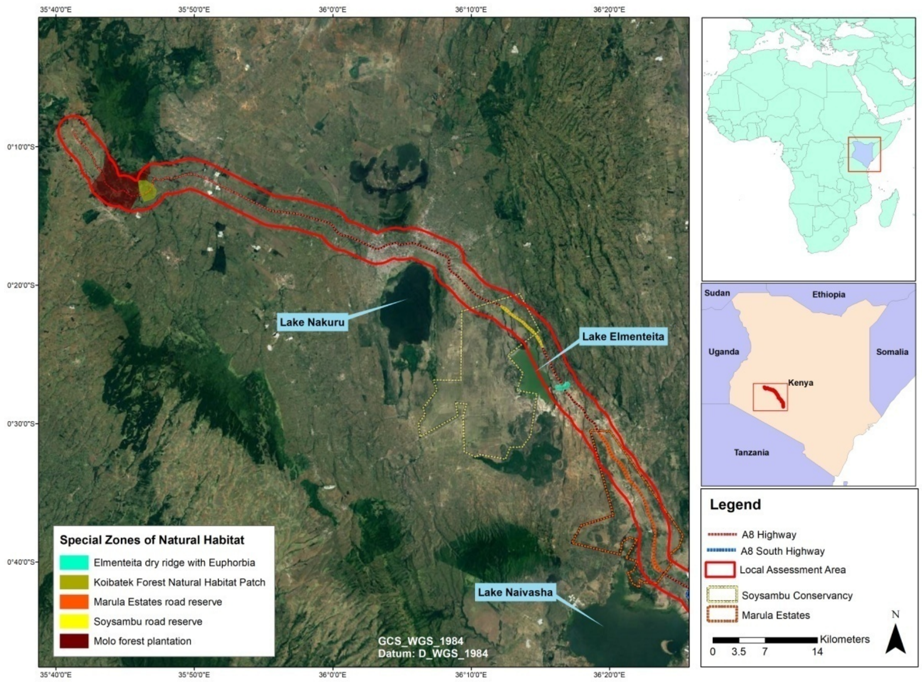
3.3. Special Zones of Natural Habitat

The A8 highway traverses predominantly though Modified Habitat (see Bennun et al., 2018), although some sections of the Local Assessment Area along the road upgrade may cause the loss of small areas of Natural Habitat that are of interest. These areas (herewith referred to special zones according to Bennun et al., 2018) include mainly untransformed or semi-transformed habitat with compositions of unique biodiversity life forms, which inter alia may include threatened, endemic and/ or biome-restricted bird species. These special zones are summarised in Table 2 and **Error! Reference source not found.**. Appendix 3 provides photographic examples of each of the special zones as observed on the Local Assessment Area.

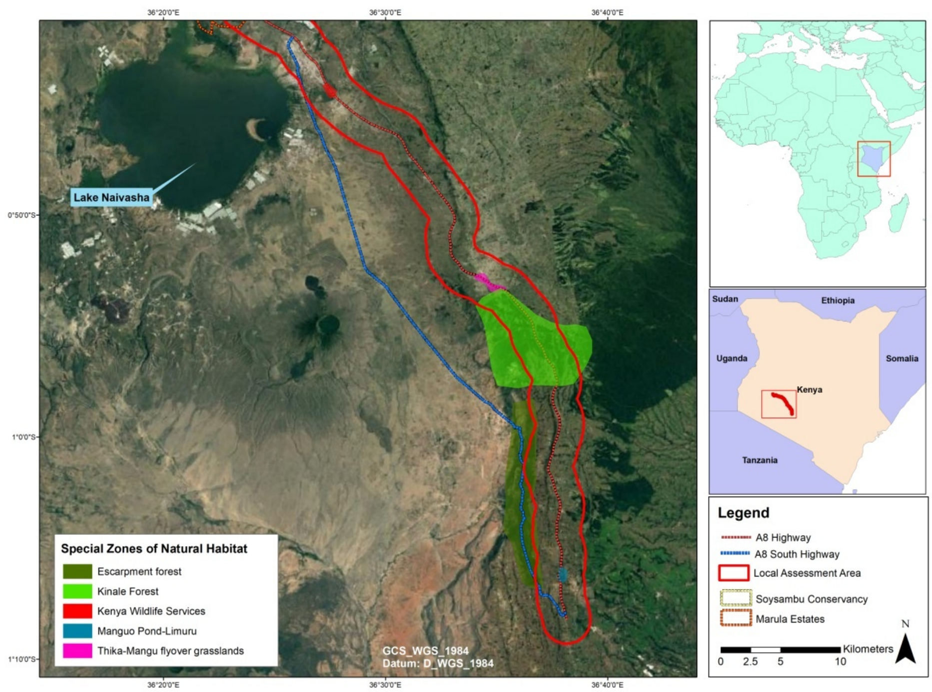
Table 2: The special zones of Natural Habitat corresponding to the Local Assessment Area that was surveyed during the avifaunal investigation.

Special Zone	Description
1. Kinale Forest	Small patches of indigenous forest and scrub located along the road alignment, although large tracts of untransformed forest occur in the Gatamaiyo Forest Nature Reserve east of the road alignment These patches, including the regenerating understory of indigenous shrubs and trees under the plantations, are potentially important in maintaining connectivity between indigenous forest on the escarpment and in the Kikuyu Escarpment Forest (an Important Bird Area) to the north-east. The Kikuyu Escarpment Forest, of which the Kinale Forest block is part of, holds important numbers of bird species restricted to the Afrotropical Highlands Biome (mainly forest-dependant species). It also forms the core distribution of the globally vulnerable Abbott's Starling (*Poeoptera femoralis*).
2. Thika-Mango flyover grasslands	This zone includes small patches of degraded and fragmented highland grassland between Kinale Forest and the Thika-Mango flyover, and provides a potential dispersal corridor for bird and animal species to the Kinale forest.
3. Kenya Wildlife Service sanctuary	The Kenya Wildlife Service sanctuary contains large stands of mature Leleshwa (*Tarchonanthus*) and *Acacia*-dominated shrubland in an otherwise urban landscape (located in Naivasha). The Kenya Wildlife Service sanctuary provides habitat for the localised *chyuluensis* subspecies of the Long-billed Pipit (*Anthus similis*) known as the "Nairobi Pipit". This subspecies of the Long-billed Pipit is currently only known from an area between Nairobi to the Chyulu Hills.
4. Marula Estates road reserve	This zone lies within the road reserve where it borders the Marula Estates. It includes mature and good examples of *Acacia xanthophloea* woodland.
5. Soysambu road reserve	This zone lies within the road reserve adjacent to the Soysambu Conservancies, between Naivasha and Nakuru. It contains open dry grassland and mature examples of Leleshwa and *Acacia* habitats.
6. Koibatek Forest Patch	This zone includes a small section of indigenous forest where the road crosses the Koibatek Forest from Sachangwan to Kibunja trading center. It provides habitat for many forest-dependant bird species.
7. Molo forest-plantation zone	This zone includes a mosaic of indigenous forest patches within plantations. It is located immediately to the north of the Koibatek forest patch and provides habitat for a diverse composition of forest bird species.
8. Manguo Pond	This is a large seasonally inundated wetland depression north-east of the road just beyond the Limuru Flyover. It is an important breeding and foraging habitat for waterbird species, including large numbers of waterbirds (especially Red-knobbed Coot *Fulica cristata* and White-faced Whistling Ducks *Dendrocygna viduata*). A pair of the globally endangered Grey Crowned Crane (*Balearica regulorum*) is also present.
9. Elmenteita dry ridge habitat	This zone includes deep valleys and ridges near Lake Elmenteita. It differs from the dominant vegetation in the area since it is covered in arid shrubland with a high prevalence of sclerohyllous and succulent plant species (including *Euphorbia* species).

Special Zone	Description
8. Escarpment forest	This unit is located along the A8 South road on the escarpment west of the main A8 highway. It consists of large section of contiguous indigenous forest. It forms a corridor via the Kinale forest zone with the Kikuyu Escarpment Forest.



a)



b)

Figure 2: The spatial location of special zones of Natural Habitat on the Local Assessment Area (located within a 2 km survey/ buffer area of on either side of the road). (a) **-** Northern part of survey area and (b) **-** southern part of survey area.

3.4. Important Bird and Biodiversity Areas (IBAs)

The avifaunal importance of a particular area is often analysed based on BirdLife International's criteria to evaluate and identify Important Bird Areas (IBAs). Criteria used to identify IBA's are outlined by the BirdLife International Secretariat (Fishpool, 1997):

- Category A1: the regular presence of significant numbers of globally threatened species. In general, only IUCN species listed as Critically Endangered, Endangered or Vulnerable are considered. The regular presence of a Critical or Endangered species, irrespective of population size, at a site may be sufficient for a site to qualify as an IBA. For Vulnerable species, the presence of more than threshold numbers at a site is necessary to trigger selection;
- Category A2: the area holds a significant component of a group of species whose breeding distributions are restricted to an Endemic Bird Area (EBA) or Secondary Area. In other words, an EBA provides habitat for two or more species with restricted ranges co-occur and have global distributions of less than 50 000 km². It is noteworthy that 70 % of these species are also globally threatened. A Secondary Area (SA) holds one or more restricted-range species, but does not qualify as an EBA because less than two species are entirely confined to it. A typical SA includes a single restricted-range species which does not overlap in distribution with any other restricted-range species.
- Category A3: the area holds significant numbers of species whose distributions are largely confined to one biome. These species have shared distributions greater than 50 000 km².
- Category A4: the area may qualify on any one or more of the four criteria listed below:
    - The area is known to hold on a regular basis more or less 1 % of a biogeographic population of a congregatory waterbird species.
    - The area is known to hold on a regular basis more or less 1 % of the global population of a congregatory seabird or terrestrial species.
    - The area is known or thought to hold on a regular basis more or less 20 000 waterbirds or more or less 10 000 pairs of seabirds of one or more species.
    - The area is known or thought to exceed thresholds set for migratory species at bottleneck sites.

There are 67 Important Bird Areas in Kenya (Stevenson and Fanshawe, 2020), of which four are relevant to the project due to the close proximity of these areas to the survey area. All four relevant IBA's are described along with their key bird compositions in Table 3 below. Figure 3 provides an approximate spatial position of each IBA in relation to the Local Assessment Area.

Table 3: The Important Bird Areas in close proximity to the survey area (Bennun and Njoroge, 1999 & BirdLife International, 2021).

IBA	Description	Key Bird species/compositions
1. Kikuyu Escarpment forest (KE003)	Located near the south-eastern part of the study site. It forms part of a forest reserve and is approximately 37 600 ha in total. It incorporates the Kinale and Gatamaiyu forests.	• It includes the core distribution of the globally vulnerable Abbott's Starling (*Poeoptera femoralis*). • The forest forms the eastern limit of many forest-dependant birds in Kenya (c. Orange Ground-thrush *Geokichla gurneyi*) and the western limit of the Red-chested Owlet (*Glaucidium tephronotum*). • The globally near threatened Crowned Eagle (*Stephanoaetus coronatus*) is resident in the forest. • It supports three species restricted to the Kenyan mountains EBA[4]. • It supports 40 species restricted to the Afrotropical Highlands Biome.
2. Kinangop Grasslands (KE004)	Located to the west of the A8 highway alignment on the Kinangop Plateau, and bounded at the west and north by the 2 400 m contour, It is unprotected and is approximately 77 000 ha in total.	• It was formerly the world stronghold of the endemic Sharpe's Longclaw (*Macronyx sharpei*). • It is an important flyway for Palearctic migratory species on passage. • It support grassland habitat for localised bird species such as Black-winged Lapwing (*Vanellus melanopterus*), Wing-snapping Cisticola (*Cisticola ayresii*), Jackson's Widowbird (*Euplectes jacksoni*) and Long-tailed Widowbird (*E. progne*). • It supports four species restricted to the Kenyan mountains EBA.

[4] EBA - Endemic Bird Area

IBA	Description	Key Bird species/compositions
3. Lake Elmenteita (KE046)	A shallow alkaline lake located on the central part the survey area and immediately west of the A8 highway alignment, It is partly protected and is approximately 7 200 ha in total.	• The surrounding woodlands support a small population of the range-restricted Grey-crested Helmetshrike (*Prionops poliolophus*). • The lake holds internationally important numbers of Greater Flamingo (*Phoenicopterus ruber* - 23 800 individuals), Lesser Flamingo (*P. minor* - 588 400 individuals), Pied Avocet (*Recurvirostra avosetta* - 4 200 individuals), Great White Pelican (*Pelecanus onocrotalus* - 8000 breeding pairs), Black-necked Grebe (*Podiceps nigricollis* - 3000 individuals) and African Spoonbill (*Platalea alba* - 260 individuals). • The lake supports over to 500 000 waterbird individuals. • It is an important staging (feeding) site for Palearctic waders when on passage. • It supports one species restricted to the Kenyan mountains EBA. • It supports one species restricted to the Serengeti Plains EBA.
4. Lake Naivasha (KE048)	A shallow freshwater lake located on the south-central part the survey area and immediately west of theA8 highway alignment, It is a Ramsar Site and is approximately 23 600 ha in total.	• The surrounding woodlands support a small population of the range-restricted Grey-crested Helmetshrike (*Prionops poliolophus*). • The globally endangered Basra Reed-warbler (*Acrocephalus griseldis*) is a winter visitor (a Palearctic migrant). • The lake holds internationally important numbers of Little Grebe (*Tachybaptus ruficollis* - 1 500 individuals), Red-knobbed Coot (*Fulica cristata* - 19 400 individuals) and African Spoonbill (*Platalea alba* - 412 individuals). • The lake supports up to 20 000 waterbird individuals. • It supports one species restricted to the Serengeti Plains EBA.

IBA	Description	Key Bird species/compositions
5. Lake Nakuru National Park (KE049)	A shallow alkaline lake located on the northern part the survey area and immediately south of the A8 highway alignment, It is a Ramsar Site and National Park, and is approximately 18 000 ha in total.	• The surrounding woodlands support a small population of the range-restricted Grey-crested Helmetshrike (*Prionops poliolophus*). • The globally endangered Basra Reed-warbler (*Acrocephalus griseldis*) is a winter visitor (a Palearctic migrant). • The globally endangered Madagascar Pond-heron (*Ardeola idae*) is a winter visitor (from Madagascar). • It is an important staging (feeding) site for Palearctic waders when on passage. • The lake holds internationally important numbers of Little Grebe (*Tachybaptus ruficollis* - 7 860 individuals), Greater Flamingo (*Phoenicopterus ruber* - 9 940 individuals), Lesser Flamingo (*P. minor* - 1 448 000 individuals), Black-winged Stilt (*Himantopus himantopus* - 3 120 individuals), Yellow-billed Stork (*Mycteria ibis* - 1 620 individuals), Grey-headed Gull (*Chroicocephalus cirrocephalus* - 9 040 individuals), Gull-billed Tern (*Gelochelidon nilotica* - 1 390 individuals), Great White Pelican (*Pelecanus onocrotalus* - 44 430 individuals), Black-necked Grebe (*Podiceps nigricollis* - 600 individuals)and African Spoonbill (*Platalea alba* - 580 individuals). • The lake supports over 1 000 000 waterbird individuals. • It supports one species restricted to the Serengeti Plains EBA.

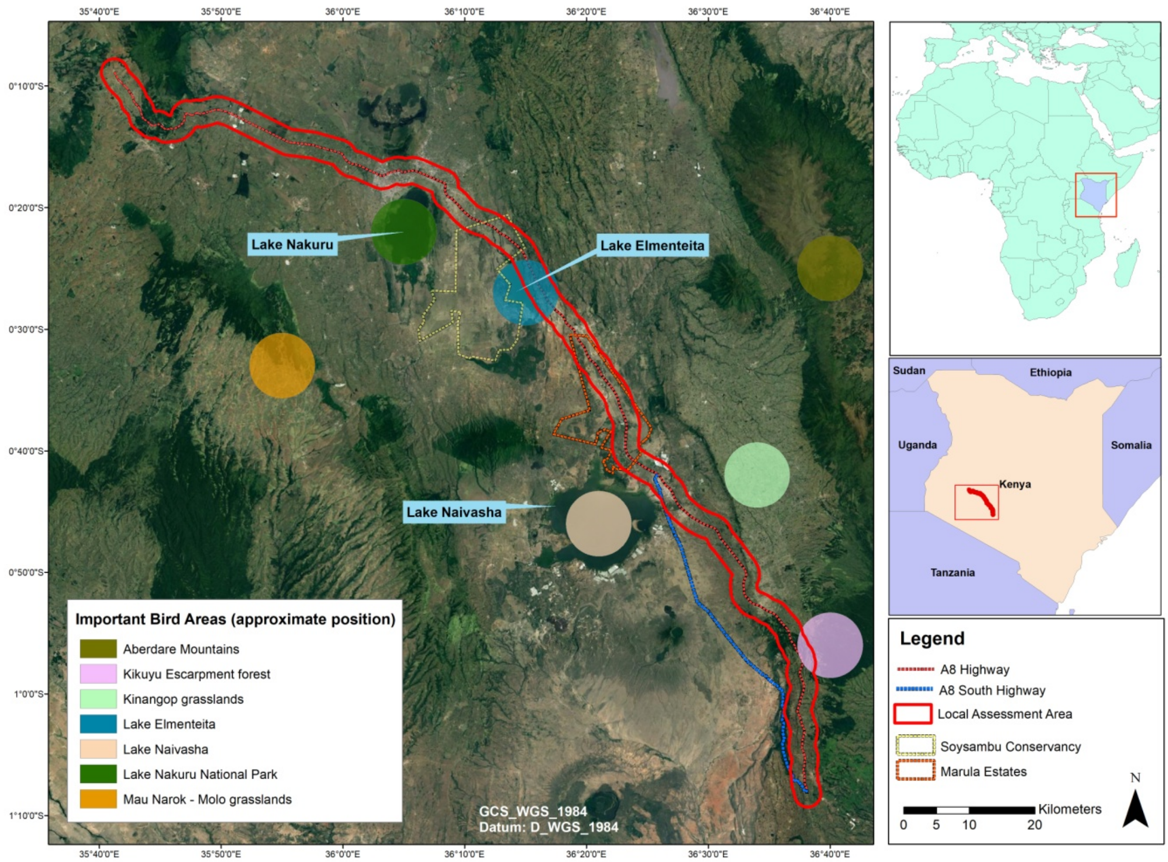


Figure 3: The approximate spatial location of Important Bird Areas that are in close proximity to Local Assessment Area of the project.

4. METHODS

4.1. Literature Review

A desktop and literature review of the survey area was commissioned to collate as much information as possible. The following literature (apart from those cited elsewhere in this document) was regarded as key references to the assessment:

- del Hoyo *et al.* (1992-2011), Sinclair & Ryan (2010), Stevenson and Fanshawe (2020) and Zimmerman et al. (2005) were consulted for general information on the life history attributes of relevant bird species that are resident/prevalent in the survey area.
- Distributional data (apart from those obtained during the surveys) was sourced from Stevenson and Fanshawe (2020), Zimmerman et al. (2005) and an atlas produced by Lewis and Pomeroy (1989) to assist with the compilation of an expected shortlist of bird species that could potentially occur in the survey area.
    - Lewis and Pomeroy (1989) provides a "snapshot" of the distribution of species recorded within quarter degree grid cells (QDGC) which was the sampling unit chosen (corresponding to an area of approximately 15 min latitude x 15 min longitude). It should be noted that this publication is outdated since it provides an indication of the thoroughness of which the QDGCs were surveyed between 1970 and 1984. Most of the records provided by Lewis and Pomeroy (1989) were carefully vetted during the compilation of the expected list since these records were collected almost thirty years ago. Much has changes in terms of habitat structure, habitat floristic composition and climatic conditions, which will also affect the distribution and abundance of current bird distribution patterns. However, it does provide insight on drastic changes to the local avifaunal distribution patterns on the study site.
    - In order to obtain recent (contemporary) distributional data, the Kenya Bird Map project (http://www.kenya.birdmap.africa) was consulted, which forms part of the African Bird Atlas Project (Figure 4). Since bird distributions are dynamic (based on landscape changes such as fragmentation and climate change) the African Bird Atlas Project was initiated (launched in 2007) with the main difference being that all sampling is done at a finer scale known as pentad grids (5 min latitude x 5 min longitude, equating to 9 pentads within a QDGC). The data is therefore site-specific, recent and more comparable with observations made during the surveys (due to increased standardisation of data collection). The data is collected by means of input from citizen scientists, who act as volunteer members of the public who are keen to contribute through going "birding" and submitting their observations to the project. For the current project, a total of 38 pentad grids are relevant to the project area, containing approximately 541 species based on 1 089 submitted full protocol[5] cards and 1 805 ad hoc submissions[6] between March 2013 and April 2021 (Figure 5). These records[7] were carefully vetted against the habitat units on the study site by eliminating species with a low probability to occur within a 2 km buffer area on either side of the road.
- The choice of scientific nomenclature, taxonomy and common names were recommended by the International Ornithological Committee (the IOC World Bird Names, version 11.1), unless otherwise specified (see www.worldbirdnames.org; Gill et al., 2021).

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[5] A minimum of two hours of observation effort per pentad grid is required for the submission of a full protocol card.
[6] Less than two hours of observation effort spent in a pentad grid.
[7] Representing 147 observers and an average 20.8 species per pentad grid (range: 1 - 123 species per pentad grid).

- The conservation status of bird species was categorised according to the IUCN Red List of threatened species (IUCN, 2021, v. 3), while their biogeographic affinities were obtained from Bennun and Njoroge (1999).

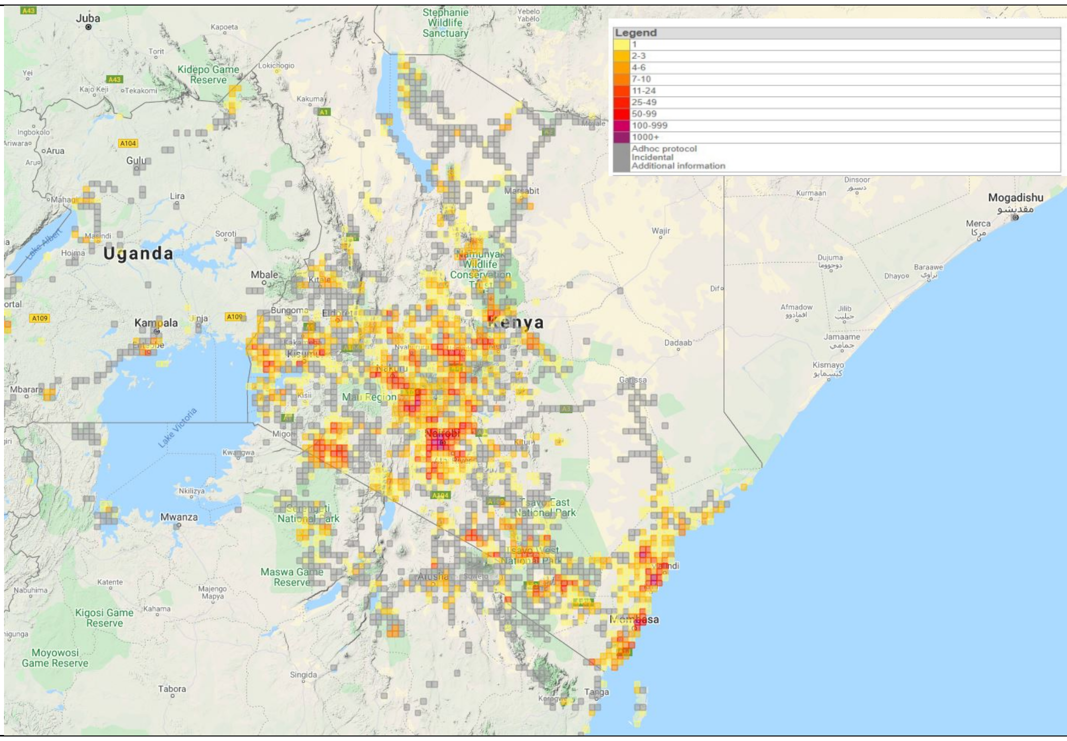


Figure 4: A map illustrating the general coverage for the Kenya Bird Map Project and the pentad grids that have been surveyed in Kenya (map courtesy of the Animal Demography Unit, Cape Town, South Africa).

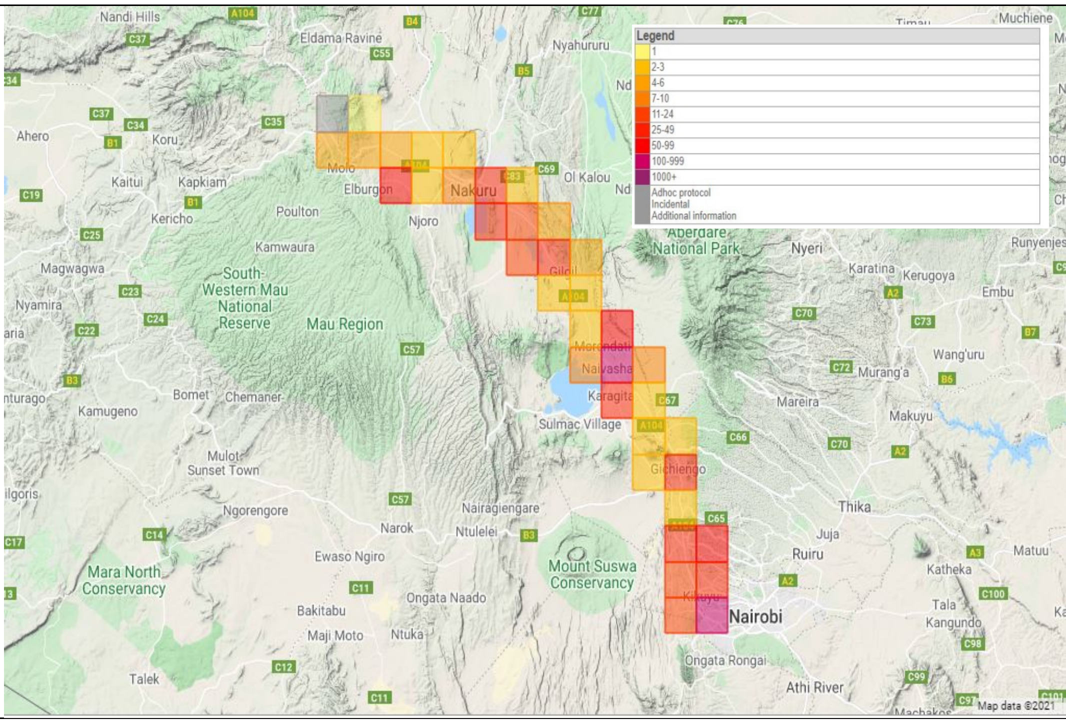


Figure 5: A map illustrating the Kenya Bird Map pentad grids relevant to the survey area that were investigated and vetted during the desktop review (map courtesy of the Animal Demography Unit, Cape Town, South Africa).

4.2. Field methodology

The avifauna on the survey area was surveyed from 17 to 26 February 2021 (10 days of field work) and from 13 to 25 April 2021 (12 days of field work) across two seasons. The February 2021 survey coincided with the late austral dry season, and the April 2021 survey covered the austral wet season. An inventory of bird species identified within the survey area as well as those expected to be present (not observed during the surveys), along with their common and scientific names is included in Appendix 1.

The baseline avifaunal survey was conducted by means of the following survey techniques:

4.2.1. Point Counts

Bird data was collected by means of 161 point counts (Buckland et al. 1993), where all birds seen and heard from a specific point over a set period of time are recorded. Birds were counted by means of 73 point counts during the dry season and 88 counts during the wet season. Data from the point counts was analysed to determine dominant and diagnostic bird species (so-called discriminant or indicator species) and to delineate the different associations present.

The use of point counts is advantageous since it is the preferred method to use for skulking or elusive species. In addition, it is the preferred method to line transect counts where access is problematic, or when the terrain appears to be complex. It is considered to be a good method to use, and very efficient for gathering a large amount of data in a short period of time (Sutherland, 2006). The spatial position of each point count is illustrated in **Error! Reference source not found.**. The spatial placement of the point counts was determined through a s tratified random design which ensures adequate coverage of each habitat type (see Table 4) (Sutherland et al., 2004).

At each point, all the bird species seen within approximately 50 m from the centre of the point were recorded along with their respective abundance values. Each point count lasted approximately 20 -30 minutes, while the area within the immediate vicinity was slowly traversed to ensure that all bird species were detected (according to Watson, 2003). To ensure the independence of observations, points were positioned at least 200 m apart. Observations were not truncated, and in order to standardise data collection, the following assumptions were conformed to (according to Buckland et al., 1994):

- All birds on the point must be seen and correctly identified. This assumption is in practice very difficult to meet in the field as some birds in the nearby vicinity may be overlooked due to dense vegetation or low visibility at some places. Therefore, it is assumed that the portion of birds seen on the point count represents the total assemblage on the point.
- All birds must be recorded at their initial location. All movements of the birds are random and therefore natural in relation to the movements of the observer. None of the birds moved in response to the presence of the observer, and birds flying past without landing were omitted from the analysis. In other words, no bird is recorded more than once.

4.2.2. Random (ad hoc) surveys

To obtain an inventory of bird species present (apart from those observed during the point counts), all bird species observed/detected while moving between point counts were identified and noted. Particular attention was devoted to suitable roosting, foraging and nesting habitat for species of conservation concern (e.g. threatened or near threatened species).

4.2.3. Nocturnal observations

It was not possible to conduct detailed surveys of nocturnal bird species due to the COVID-19 restrictions and curfews. It was only possible to survey two sites representing Afromontane undifferentiated forest (site 145) and evergreen and semi evergreen bushland and thicket (site 262) during the February 2021 campaign. At each of these sites attention was paid to the calls of specific bird species such as owls and nightjars using audio equipment by broadcasting playback of bird calls/songs. Nocturnal bird species (mainly owls and nightjars) were noted while driving to these points at night.

4.2.4. Playback/broadcasting and recording of bird vocalisations

The probability of detecting skulking/ elusive species (e.g. forest-interior species) or species for which the distribution ranges are insufficiently known in Kenya was verified by playback of bird calls/songs wherever suitable habitat was detected (e.g. ground-thrush species of the genus *Geokichla* and Bar-tailed Trogon *Apaloderma vittatum*). Special care was taken to keep disturbance to a minimum and not to affect the bird's natural behaviour (e.g. to prevent unnecessary habituation). In certain instances the calls/vocalisations of species which are confusing and problematic were recorded for later identification. A good example includes the indigobirds of the genus *Vidua*, which consists of a number of similar-looking species although the calls of the males contain mimicking notes of their host species (mainly firefinches of the genus *Lagonosticta*).

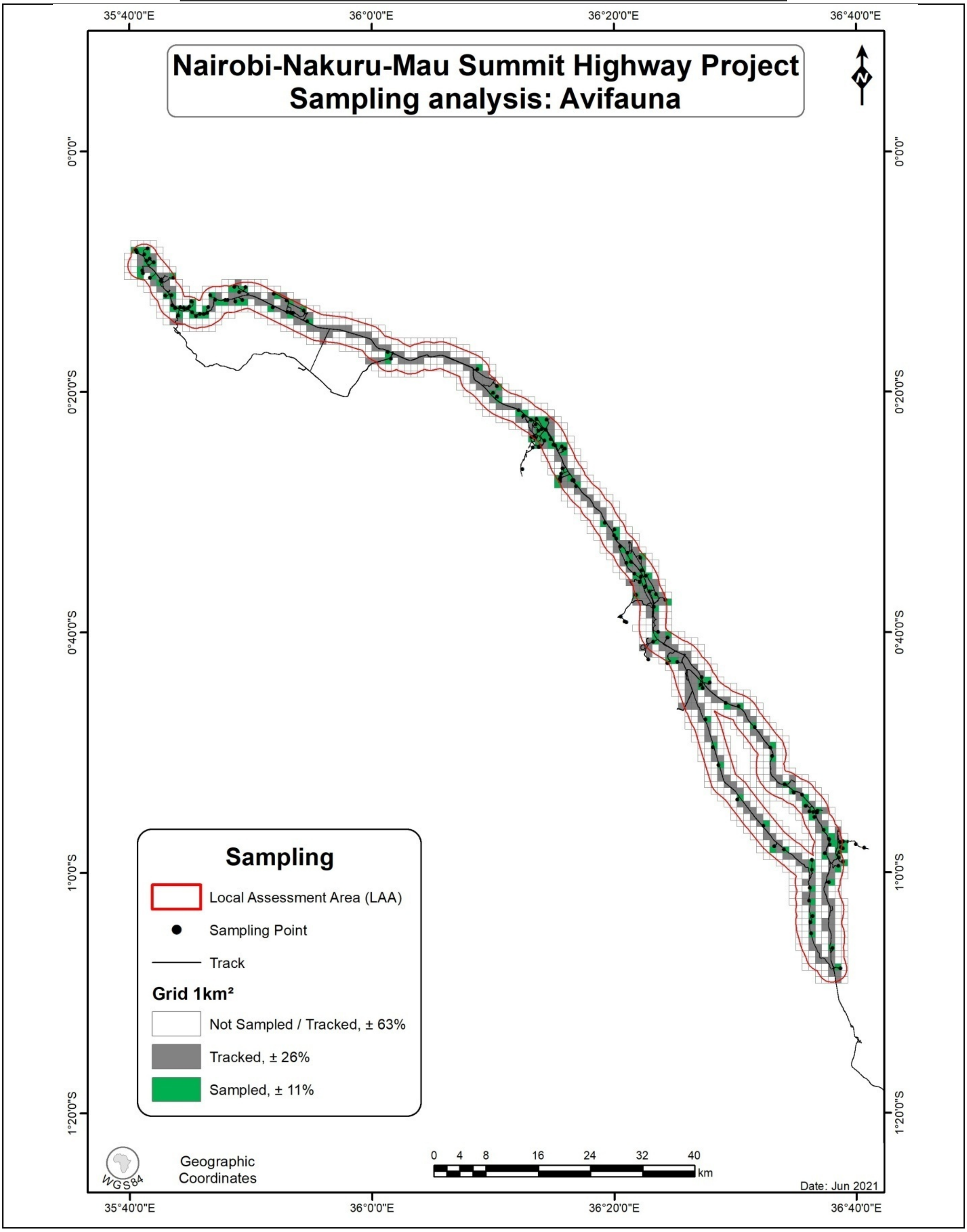


Figure 6: The spatial position of bird point counts on the survey area.

Table 4: The broad-scale habitat types corresponding to the survey area that was surveyed during the avifaunal investigation by means of point counts.

Broad-scale Habitat	Dry Season (Feb 2021)	Wet Season (Apr 2021)	Total counts (both seasons)
1. Afromontane Undifferentiated Forest (AUF)	30	17	47
2. Afromontane Rainforest (AfR)	2	8	10
3. Afromontane Bamboo (AfmB)	5	3	8
4. Upper *Acacia* Wooded Grassland (UAWG)	1	8	9
5. Evergreen and Semi evergreen Bushland and Thicket (ESEBT)	19	35	54
6. Edaphic wooded grassland (EWG)	7	4	11
7. Riverine wooded vegetation (RWV)	4	8	12
8. Halophytic vegetation (HalV)	5	5	10
Total	**73**	**88**	**161**

4.3. Exclusions, limitations and assumptions

- Findings, results, observations, conclusions, and recommendations presented in this report are based on the authors' best scientific and professional knowledge as well as the interpretation of information available to them at the time of compiling this report.
- It is assumed that third party information (obtained from government, academic/research institution, non-governmental organisations) is accurate and true.
- Public datasets (e.g. Kenya Bird Map Project) are often small-scale and do not always consider some of the azonal habitat types that may be present on survey area (e.g. dams, impoundments on private land). In addition, these datasets often also encompass surface areas larger than the survey area, which could include habitat types and species that are not present on the survey area itself. Therefore, the potential to overestimate species richness is possible, while it is also possible that certain cryptic or specialist species could have been overlooked in the past;
- Some of the datasets, such as the Kenya Bird Map Project are still in progress and plan to run indefinitely;
- The information presented in this document only has reference to the investigated survey area and cannot be applied to any other area without prior investigation.
- Results presented in this report are based on a "snapshot" investigation of the survey area and not on detailed and long-term investigations (e.g. several weeks or months) of all the environmental attributes and the varying degrees of bird diversity that may be present in the survey area. Specifically, no excessive long-term survey methods were employed in the collation of data from the site. Although as much as possible data was obtained from ad hoc observations and representative point counts during the survey period, these surveys are customarily limited by budgetary and time constraints – results presented in this report need to be interpreted with these limitations in mind.
- Rare and endemic species normally do not occur in great densities and, because of customary limitations in the search and identification of Red Listed species, any detailed autecological investigations of these species was not possible. Results are ultimately based on inferred estimations and specialist interpretation of survey data.
- Broadcasting techniques or the "call-up" of bird species to lure them into open habitat types is often controversial and sometimes referred to as "cheating" by birdwatchers. However, for its application to detect species during short timeframes, it is a technique that is widely used across the globe, and if done in moderation without causing stress during the breeding season (thereby not using it for extended periods) it is a valid method. It could only be referred to as "cheating" if a specialist is trying to call up a bird into a patch of habitat that is pre-emptively not suitable for the species to continue its life history.

However, for most bird species this will in fact be unlikely since birds don't normally venture into habitat that they find unsuitable.

- Due to COVID-19 restrictions and curfews, it was not possible to conduct nocturnal surveys apart from two brief site surveys during February 2021.

4.4. Data analysis

4.4.1. Species accumulation curves

Species accumulation curves (SAC) for the point count data were generated using the software program Estimates S (version 9) with 100 randomizations (as recommended in Colwell, 2013). Curves were generated for the full data set (all habitats types combined) as well as for each season. Sampling sufficiency was determined by establishing whether the point had been reached where a line representing one new sample adding one new species was tangent to the curve (Brewer & McCann, 1982). The Michaelis-Menten equation (Soberôn & Llorente 1993) was fitted to the predicted number of species using Estimates S (Raaijmakers, 1987). A satisfactory level of sampling was achieved if 90 % of the bird species were detected, and hence predicted by the model (Moreno & Halffter, 2000).

4.4.2. Primary analysis and matrix

All data collected were presented in a matrix, with rows representing the relative abundances of each bird species, and columns representing the respective point counts within each of the sampled habitat types (see Niemand, 2001). This matrix formed the basis for the data analyses.

The observations were converted to relative abundance values. The relative abundances of each species in each habitat type were standardized due to unequal sample sizes of the point counts in each habitat type. There are several measures to describe the similarity of species abundance values between samples, and in this study the Bray-Curtis similarity coefficient was used. The coefficient describes the similarity between species a and b (B-CSab) and was calculated as:

$$B\text{-}CSab = (2\sum \min (x\_ca,x\_cb))/(\sum x\_ca \sum x\_cb)$$

where xca and xcb are fourth-root transformed parameters (abundance, relative densities) of species a and species b respectively.

All multivariate analyses were performed using the software package Primer 5 (Plymouth Routines in Multivariate Ecological Research, version 5.2.2; www.primer-e.com). This was done by calculating Bray-Curtis similarities between every pair of samples to construct a similarity matrix. This matrix was subsequently used to discriminate between habitat types through ordination techniques (using non-metric multidimensional scaling). The importance of very abundant species had to be down-weighted in order to give some importance to low abundance or rare species. This was achieved by performing a fourth root transformation on the data (Clarke & Warwick, 1994).

4.4.3. Patterns in composition

A comparison of the different avifaunal associations relative to each habitat type was performed using multivariate community analyses of Bray-Curtis similarity coefficients. The calculated similarity matrix was exposed to a cluster analysis based on hierarchical agglomerative clustering with group-average linking, as described by Clarke & Warwick (1994). Therefore, sampling entities (point counts) that group together (being more similar) are believed to have similar bird compositions. Non-metric multidimensional scaling (NMDS) was used to map the inter-relationships between the point counts in an ordination with a specified number of dimensions (Kruskal & Wish, 1978).

Significant differences between the bird associations or samples within a cluster were tested using the program ANOSIM (Clarke & Green, 1988).

The program SIMPER was used to determine the contribution (%) of each species to each habitat type, including the consistency of its contribution (Clarke & Warwick, 1994). Species with high consistencies represent typical species for the given community. The same program was used to measure the dissimilarity between habitat types. Therefore, a species with a high contribution to the dissimilarity between two sites are diagnostic or good discriminant/indicator species of the particular habitat (Niemand, 2001).

4.4.4. Patterns in abundance and diversity

The mean number of species (S) and the Shannon-Wiener diversity index (H') were calculated for each habitat type. Please refer to Magurran (1988) for a description of the Shannon-Wiener diversity index.

Rarefaction was used to calculate the expected number of species (E[Sn]) in a random sample of n individuals less than the original sample of N individuals. The advantage of rarefaction is that it adjusts the number of species expected from each sample if all were reduced to a standard size.

Species-abundance curves were constructed for each community by plotting the relative abundance of each species against species ranks. The curves describe the equitability (evenness) among species in a community.

4.4.5. Guild Profiles

Bird guilds are used as an alternative to species lists or species inventories. Each bird association represents a “guild profile” of different trophic guilds, each represented by one or more species (Feinsinger, 2001). For example, a habitat patch may contain several species that are insectivorous, although they utilise different ways (e.g. gleaning, probing, hawking) at different strata (vertical levels) to obtain their prey. Hence, a habitat patch with a high diversity of guilds is therefore often more functional than another patch. Since richness values and species composition alone are not as good ecological indicators, the “guild profile” may be more sensitive to the effects of human-induced activities. The “guild profile” of each bird association will be analysed and interpreted (e.g. dominant guilds vs. “missing” guilds). The guild classification was based on the approach from González-Salazar et al. (2014).

4.4.6. IUCN Listed species or species with special status

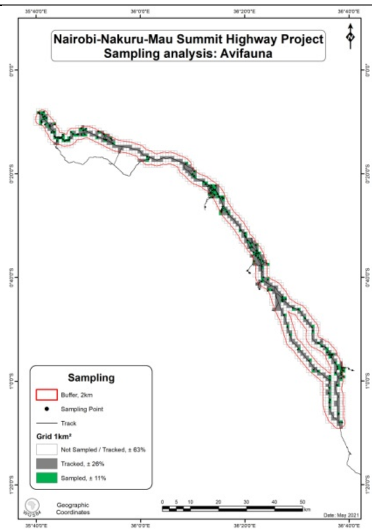
All IUCN listed species (IUCN, 2021) and biome-restricted species (, Bennun and Njoroge, 1999), including country protected species (Schedule 6 of the Wildlife Conservation and Management Act, 2013) observed and expected to occur were listed with a brief description on their probability of occurrence and habitat preference. Detailed descriptions of IUCN threatened bird species, including their inferred spatial extent of occurrence and relative abundance for observed species and / or species with a high probability of occurrence will be provided.

5. RESULTS

5.1. Sampling sufficiency and species accumulation curves

5.1.1. Spatial sampling overview – overall results

Approximately 37 % of the Local Assessment Area with a surface area ca. 718.06 km^2 (within a 2 km buffer area on either side of the A8 highway) was sampled during the dry and wet season campaigns (Figure 7). The sampling sufficiency reached approximately 11 % of the total grid cells sampled by means of point counts and approximately 26 % of the total grid cells within the Local Assessment Area were traversed on foot or by vehicle (Figure 7). Priority during sampling was given to natural habitat while aiming to visit at least each of the broad-scale habitat types and special habitat zones on the Local Assessment Area.



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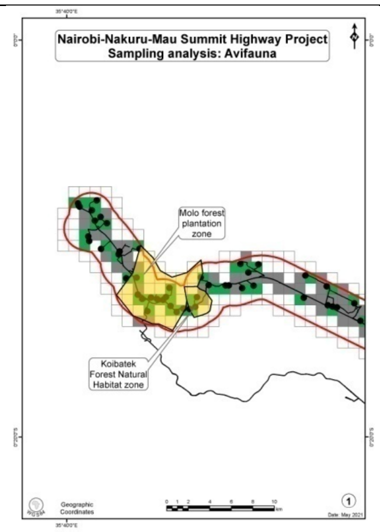

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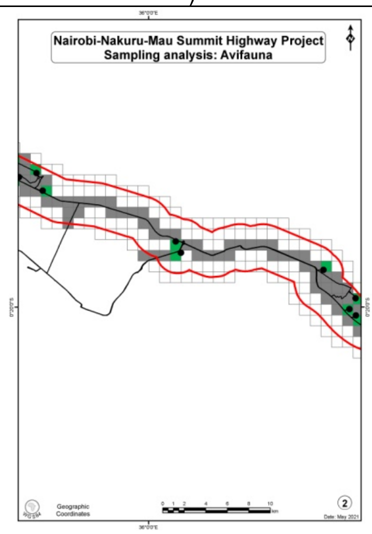

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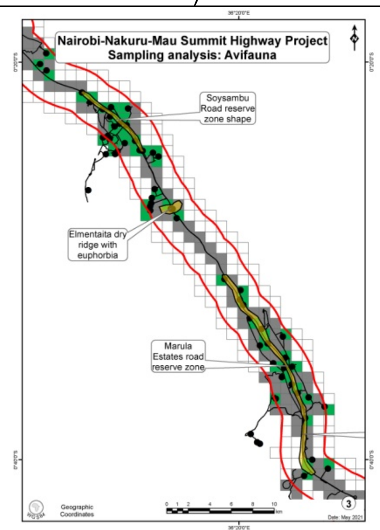

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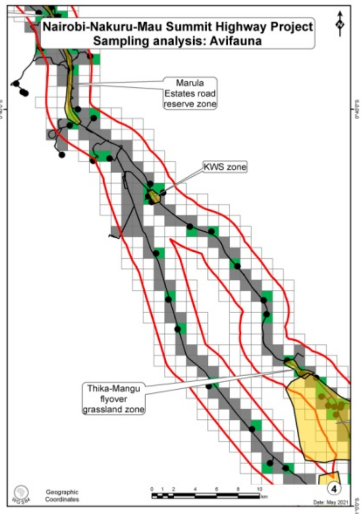

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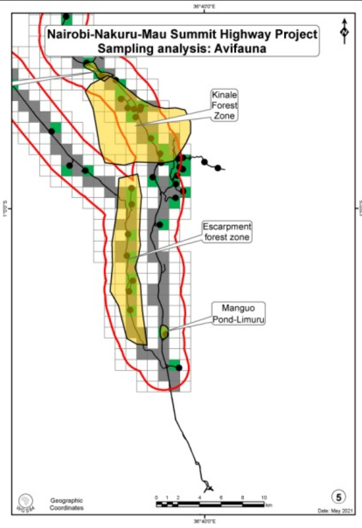


f)

Figure 7: Spatial sampling sufficiency overview for the Local Assessment Area. At the survey area level (718,06 km^2), the effort undertaken here provided a detailled overview of 431 sampling grid cells or 37% of the Local Assessment Area.

5.1.2. Species accumulation curves for the survey area – overall results

The species accumulation curve (SAC) for all bird point counts across all habitat units reached an asymptote at approximately 80 point counts (Figure 8). The sampling sufficiency captured 85 % of the number of species predicted by the Michaelis-Menten model, and 90 % of the predicted species is captured at 120 counts.

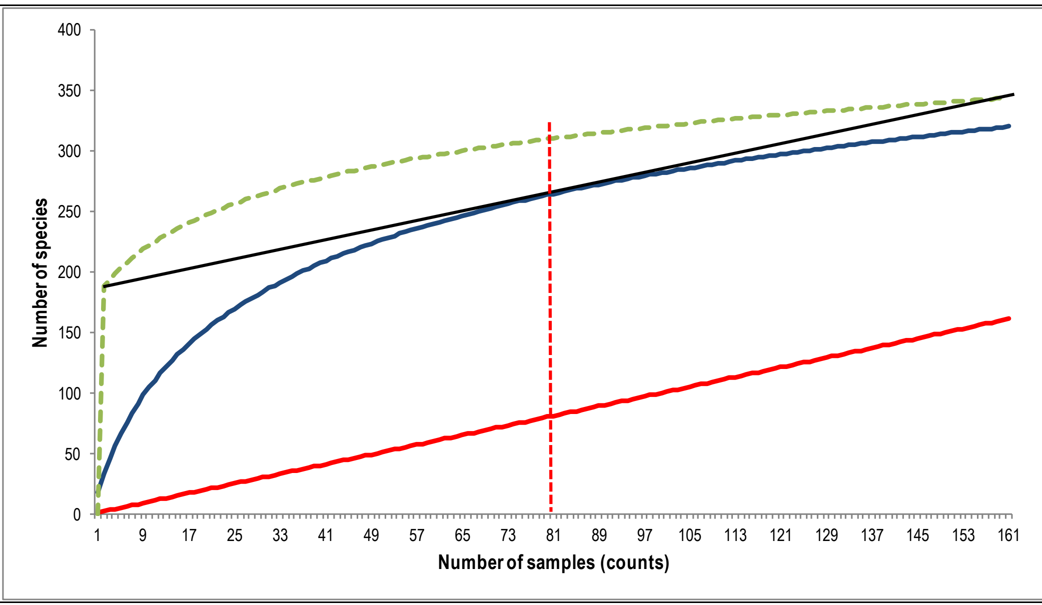
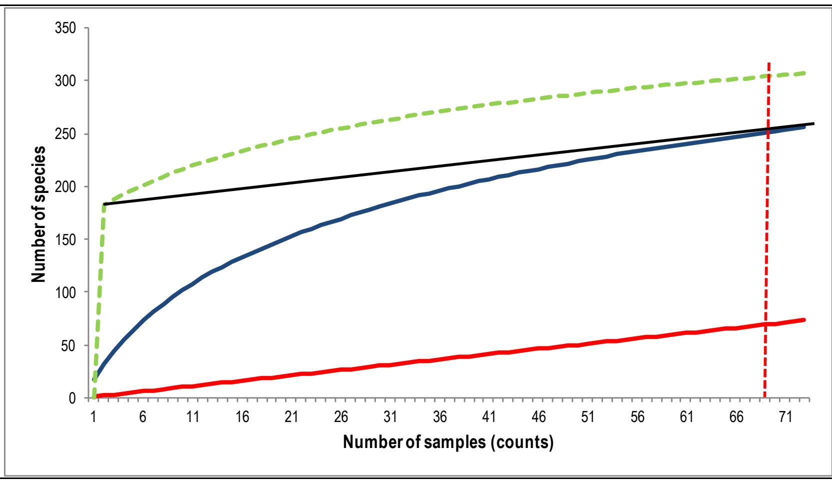


Figure 8: The species accumulation curve (SAC) (blue line) for 161 bird points when both survey campaigns are combined. The red line represents an accumulation of one species for every additional sample plot. The black line is parallel to the red one and is tangent to the SAC approximately after 80 sample sites (as represented by the vertical red stippled line). The green stippled line represents the Michaelis-Menten model-based predictor curve.

5.1.3. Species accumulation curves per season

The species accumulation curves compiled for the two seasons showed that the slope of the curves for the two seasons were marginally steeper than the line representing one new species for one new point count, despite a flattening of the curve. Sampling sufficiency during the dry and wet seasons captured respectively 83.4 and 88 % of the number of species predicted by the Michaelis-Menten model (Figure 9). We are confident that 90 % of the species were sampled during both surveys even though the Michaelis-Menten model suggested that additional sampling was required. For both seasons a flattening of the curve was observed at 70 and 80 samples for the dry and wet season respectively, thereby capturing 82.6 and 87 % of the number of species predicted by the Michaelis-Menten model.



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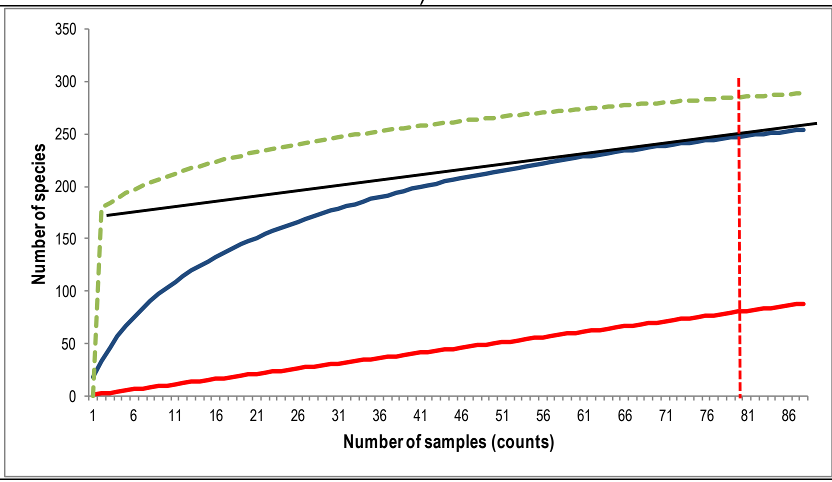

b)

Figure 9: The species accumulation curves (SAC) (blue line) for two seasons: (a) Dry season and (b) Wet season. The red line represents an accumulation of one species for every additional sample plot. The black line is parallel to the red one and shows that the slope for both seasons flattened to such an extent that the slope of the black line is tangent to the blue one. The green stippled line represents the Michaelis-Menten curve.

5.2. Summary of Taxonomic Diversity

The surveys produced 439 bird species for the survey area (see Appendix 1 & Table 5), with 375 species recorded during the dry season (February, 2021) and 368 during the wet season (April, 2021). The observed richness equates to 38 % of the approximate 1,162 species listed for Kenya (according Lepage, 2021). According to the Kenya Bird Map Project (2009) along with the availability of suitable habitat, an additional 162 species are also expected to occur, bringing the total of bird species on the study site to 601 species.

Of the observed species, 19 are threatened or near threatened according to the IUCN Red-list (IUCN, 2021), ten species are endemic to East Africa (these also occur in Tanzania and Uganda) and one species is endemic to Kenya (c. Kikuyu White-eye *Zosterops kikuyuensis*). In addition, 80 of the observed species (18 %) are migratory, representing both breeding and non-breeding visitors to the area. About 61 of the observed species represent Palearctic migrant birds and 19 species represents Intra-African migrant birds. Three of the observed species are range-restricted taxa (restricted to an Endemic Bird Area), while 62 of the observed species are restricted to a particular biome. In addition, 92 of the observed species (21 %) are waterbird taxa

The observed list also includes four introduced species which occur as either feral or naturalised populations in towns and villages:

- Rock Dove (*Columba livia),* where it is widespread in towns and larger villages. There are no wild populations of this species in Kenya.
- House Sparrow (*Passer domesticus*), where it is widespread in towns and villages.
- Fisher's Lovebird (*Agapornis fischeri*), where it is common around several towns and adjacent woodland, especially around Naivasha. The population in Kenya originated from escaped birds and is expanding its range in the country. It also hybridises with Yellow-collared Lovebird (*A. personatus*). It is endemic to Tanzania where it is a near threatened species.
- Yellow-collared Lovebird (*Agapornis personatus*), where it is common in woodland and wooded grassland. The Kenyan population stems from introduced birds which hybridises with Fisher's Lovebird (*A. fischeri*) and most of the lovebird flocks in the survey area consists of both lovebird species and hybrid birds. *A. personatus* is native to Tanzania, where it is endemic.

Table 5: A summary table of the total number of species, species of conservation concern, endemics and biome-restricted species observed on the survey area. Values in brackets refer to derived totals (%) compared against the number of species recorded for Kenya (expected) and the observed totals compared against the number of species expected on the survey area (observed).

Parameter	Expected (% of National estimate)	Observed (% of expected estimate)
Total number of species (Lepage, 2021)	601 (52 %)	439 (73 %)
Number of globally threatened/near threatened species (IUCN, 2021)	27 (31 %)	19* (70 %)
Number of East African endemic species (shared with Tanzania and Uganda)	14 (37 %)	10 (71 %)
Number of species endemic to Kenya ("true endemics")	2 (18 %)	1 (50 %)
Number of species restricted to the Serengeti Plains Endemic Bird Area (Bennun and Njoroge,1999)	1 (33 %)	1 (100 %)
Number of species restricted to the Kenyan Mountains Endemic Bird Area (Bennun and Njoroge,1999)	4 (50 %)	2 (50 %)
Number of species restricted to the Afrotropical Highlands Biome (Bennun and Njoroge,1999)	50 (71 %)	44 (88 %)
Number of species restricted to the Somali-Masai Biome (Bennun and Njoroge,1999)	21 (22 %)	7 (33 %)
Number of species restricted to the Lake Victoria basin biome (Bennun and Njoroge,1999)	1 (11 %)	1 (100 %)

* - The near threatened Fisher's Lovebird (*Agapornis fisheri*) was excluded since the population in Kenya feral and is not native to the country (it is native to Tanzania).

According to Table 5, the observed number of species is within the limit of the number of species expected to occur (>50 %), and provides a realistic indication of the thoroughness and general coverage of the survey area during the survey periods.

5.3. Out of range species and New Distribution Records

Approximately seven of the bird species observed on the survey area have not previously been recorded in the area according to Lewis and Pomeroy (1989) and the Kenya Bird Map Project. The following species are considered out of range species:

- ***Somali Bunting (Emberiza poliopleura)***: The Somali Bunting is essentially a species restricted to the Somali-Masai Biome where it prefers open dry bush habitat. The nearest recent records of this species are from the Nairobi area in the south and the Kerio Valley in the north. A pair was observed on 20 April 2021 from open Leleshwa woodland near the northern extent of the Marula Estate/Kigio Conservancy and approximately 7km south of Kikopei (S0 31 28.3 E36 20 05.2 - site 396) (Figure 10).

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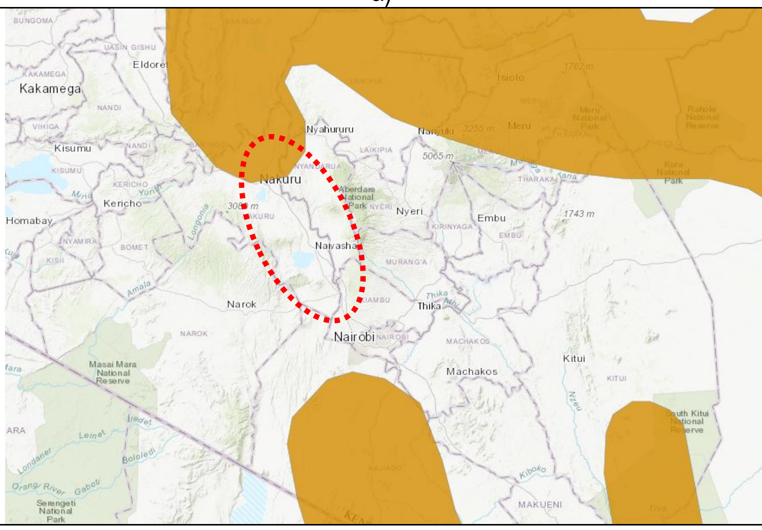
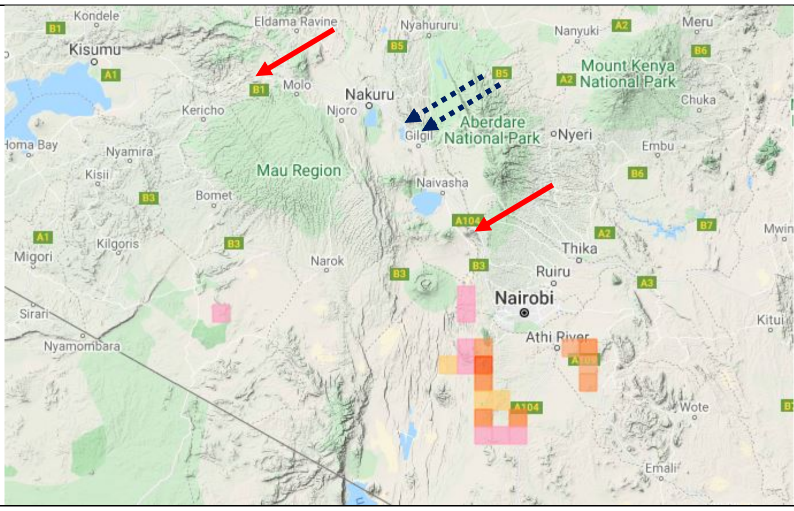


b)

Figure 10: The extant distribution range of the Somali Bunting (*Emberiza poliopleura*) relative the survey area according to (a) the Kenya Bird Map and (b) IUCN (2021). The red arrows and dashed circle show the approximate distribution limits of the survey area. The stippled arrow shows the approximate position where the species was observed during the surveys.

- ***Southern Grosbeak-canary (Crithagra buchanani)***: The Southern Grosbeak-canary is a species restricted to the Somali-Masai Biome where it prefers dry bush habitat along dry drainage lines. The nearest recent records of this species are south of Nairobi. It was recorded from two independent observations (c. 17 April 2021) in woodland near the shoreline of Lake Elmenteita. Both records were from the Soysambu Conservancy (Figure 11).



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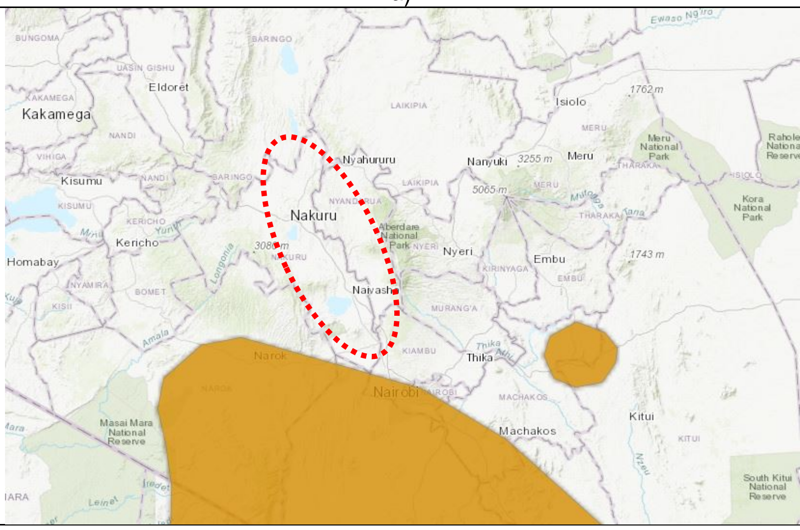
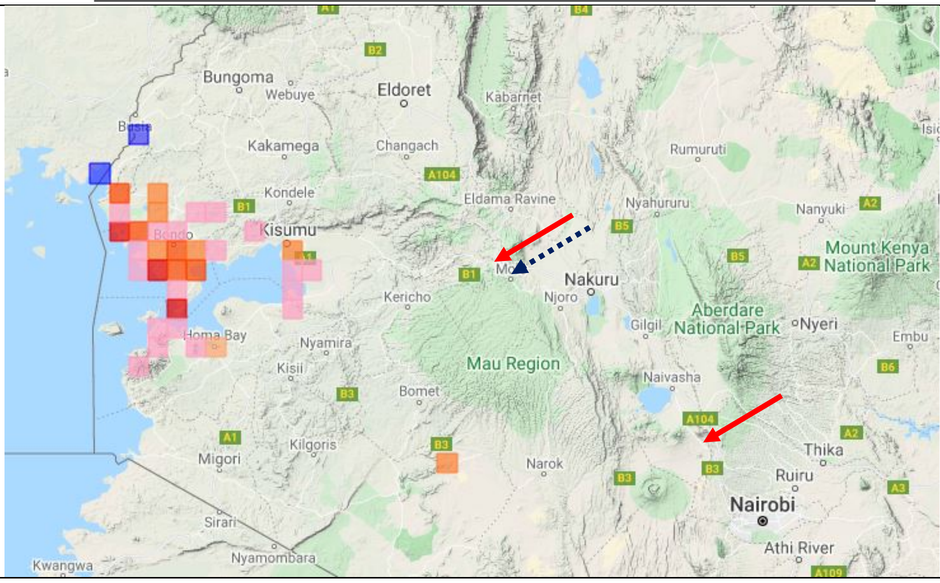


b)

Figure 11: The extant distribution range of the Southern Grosbeak-canary (*Crithagra buchanani*) relative the survey area according to (a) the Kenya Bird Map and (b) IUCN (2021). The red arrows and dashed circle show the approximate distribution limits of the survey area. The stippled arrow shows the approximate position where the species was observed during the surveys.

- ***Southern Red Bishop (Euplectes orix)***: The Southern Red Bishop is a species restricted to the southern parts of Kenya and around Lake Victoria, although it was confirmed from a small wetland (EWG) at the northern section of the survey area near the Mau Summit on 17 February 2021 (Figure 12). According to the IUCN (2021), an isolated sub-population persists in the Nakuru area.



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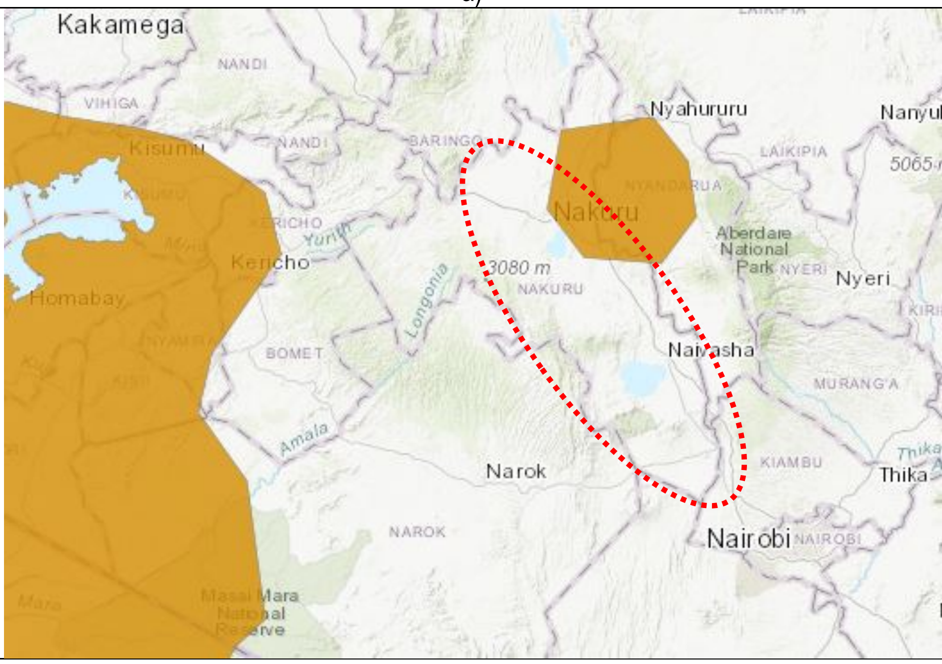
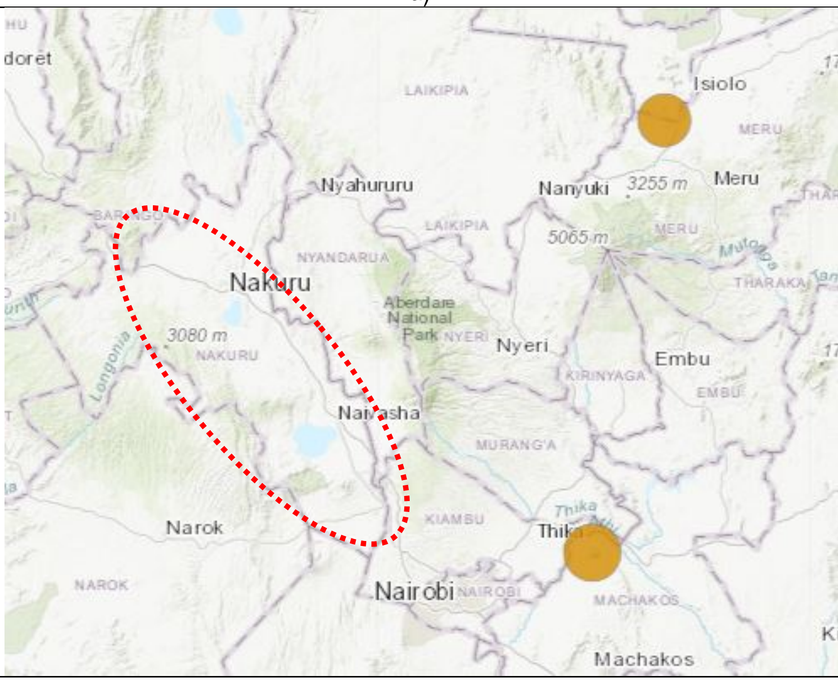


b)

Figure 12: The extant distribution range of the Southern Red Bishop (*Euplectes orix*) relative the survey area according to (a) the Kenya Bird Map and (b) IUCN (2021). The red arrows and dashed circle show the approximate distribution limits of the survey area. The stippled arrow shows the approximate position where the species was observed during the surveys.

- ***Orange-winged Pytilia (Pytilia afra)***: The Orange-winged Pytilia is extremely rare in Kenya with only a few records for the country. It was confirmed from ESEBT woodland near the entrance to the Soysambu Conservancy on 17 April 2021(Figure 13).

a)

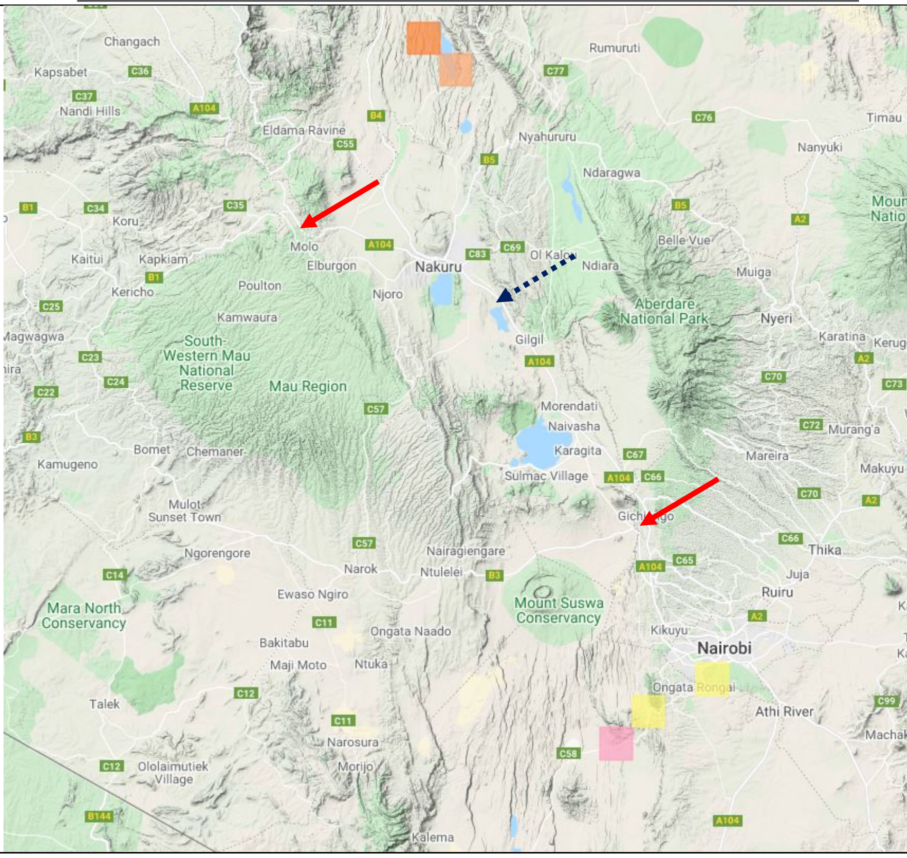


b)

Figure 13: The extant distribution range of the Southern Red Bishop (*Euplectes orix*) relative the survey area according to (a) the Kenya Bird Map and (b) IUCN (2021). The red arrows and dashed circle show the approximate distribution limits of the survey area. The stippled arrow shows the approximate position where the species was observed during the surveys.

- ***Eastern Violet-backed Sunbird (Anthreptes orientalis)***: The Eastern Violet-backed Sunbird shows a scattered distribution range in Kenya where it is mainly confined to semi-arid bush with flowering

Loranthus or *Acacia* shrub. It was observed from open secondary shrubland on 20 February 2021 north of Lake Elmenteita (Figure 14).



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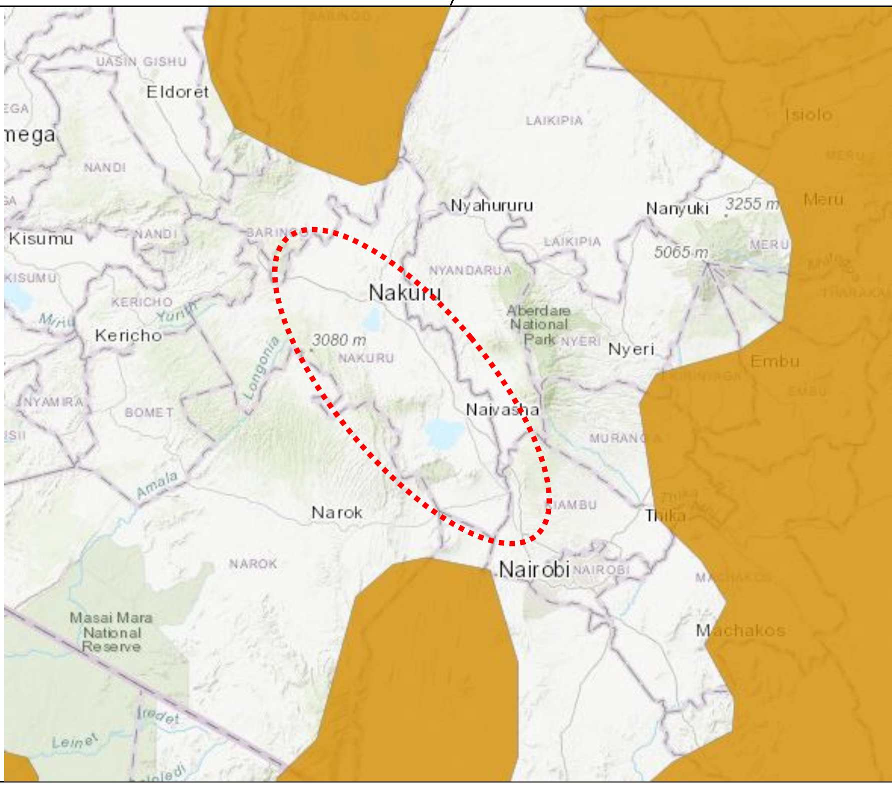

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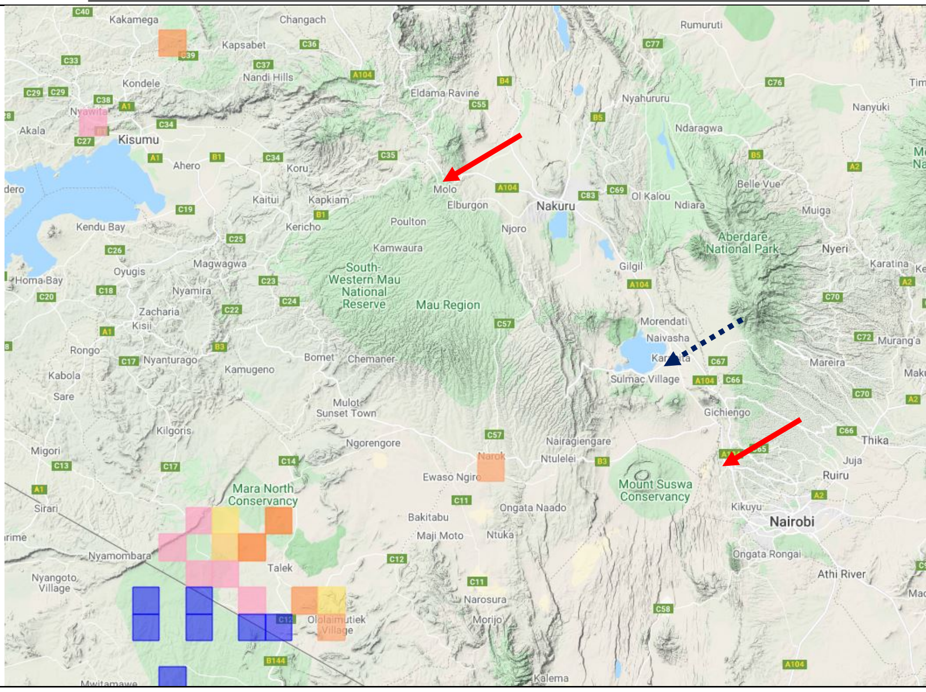
Figure 14: The extant distribution range of the Eastern Violet-backed Sunbird (*Anthreptes orientalis*) relative

the survey area according to (a) the Kenya Bird Map and (b) IUCN (2021). The red arrows and dashed circle show the approximate distribution limits of the survey area. The stippled arrow shows the approximate position where the species was observed during the surveys.

- ***Yellow-mantled Widowbird (Euplectes macroura)***: The core distribution of the Yellow-mantled Widowbird distribution lies within the western and south-western parts of Kenya where it is confined to moist grassland. It was observed from a single locality in open savannoid habitat along the A8 South Highway on 23 April 2021 (Figure 15).



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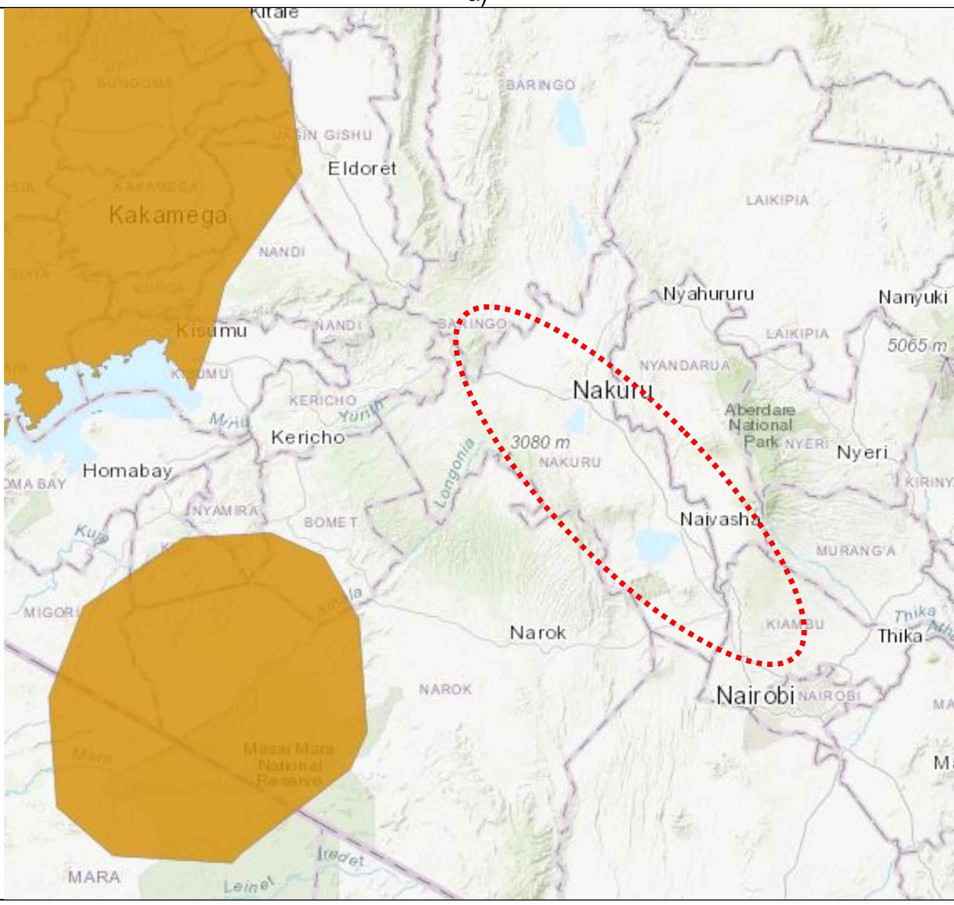


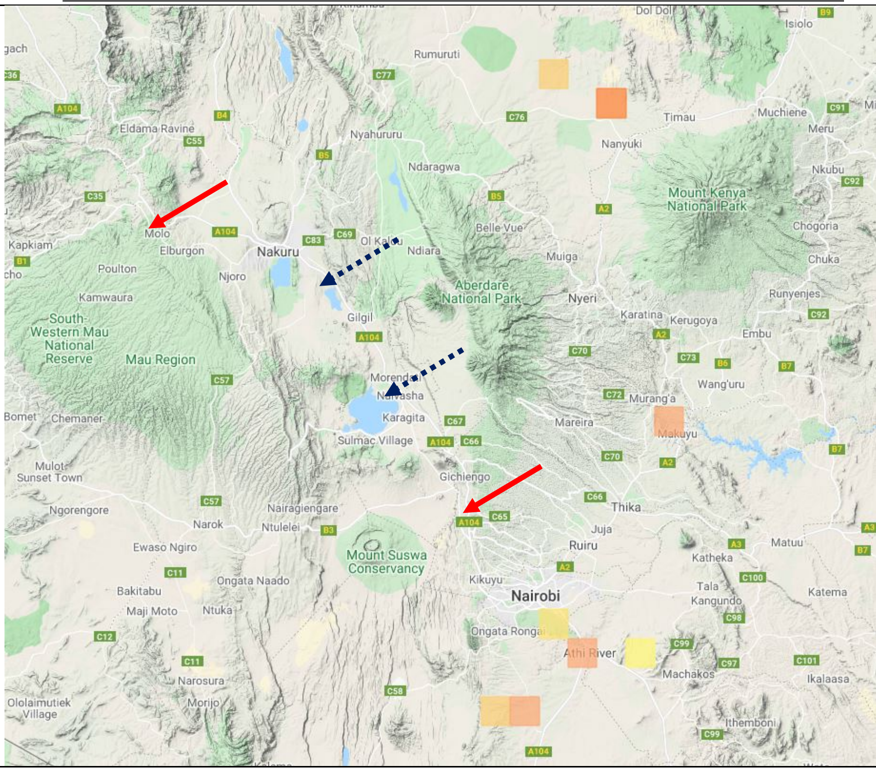
b)

Figure 15: The extant distribution range of the Yellow-mantled Widowbird (*Euplectes macroura*) relative the survey area according to (a) the Kenya Bird Map and (b) IUCN (2021). The red arrows and dashed circle show the approximate distribution limits of the survey area. The stippled arrow shows the approximate position

where the species was observed during the surveys.

- ***Grant's Wood-hoopoe (Phoeniculus granti)***: The Grant's Wood-hoopoe occurs to the east of the Rift Valley where it favours semi-arid bush and woodland along rivers. It was observed on two occasions on 21 February 2021 in leleshwa shrub in the northern part of the Soysambu Conservancy, and again 25 February 2021 along riverine woodland at the western perimeter of Naivasha town (c. RWV) (Figure 16). This species is notoriously difficult to distinguish from the similar *niloticus* subspecies of the Green Wood Hoopoe (*P. purpurascens*) which is found in the north-west of Kenya and shows more violet hues on the wings and and back, and therefore requires careful examination of the head region (which always show some green hues in *P. purpurascens)*. However, observations from the nearby Lake Nakuru National Park and the Malewa River near Gilgil (near the Kigio Conservancy) also reported the near absence of green hues in Wood-hoopoes which seems to point to Grant's Wood-hoopoe. Museum skins examined at the Nairobi Museum showed that colouration of *P. granti* and the *niloticus* subspecies of *P. purpurascens* were extremely similar and that the green hue of *P. purpurascens* only showed at certain angles (de Bruijn, 2002), thereby complicating the identification of Wood-hoopoe's in the Rift Valley. However, the birds observed during the surveys had prominent violet sheens (not greenish) on the head and upperparts (Figure 17), and the behaviour and vocalisations of these birds were consistently different to that of the residing *P. purpurascens* birds. We concur that this species is definitely overlooked in the Rift Valley and the possibility exists that observations were dismissed in the past as *P. purpurascens*[8].

[8] The author has experience in identifying *Phoeniculus granti* from *P. purpurascens* based on coloration, behaviour and subtle differences in vocalisations between the two species. In addition, the author is also familiar with the conspecific and identical *P. damarensis* which occurs in SW Africa (e.g. Namibia) which was previously lumped with *P. granti.*



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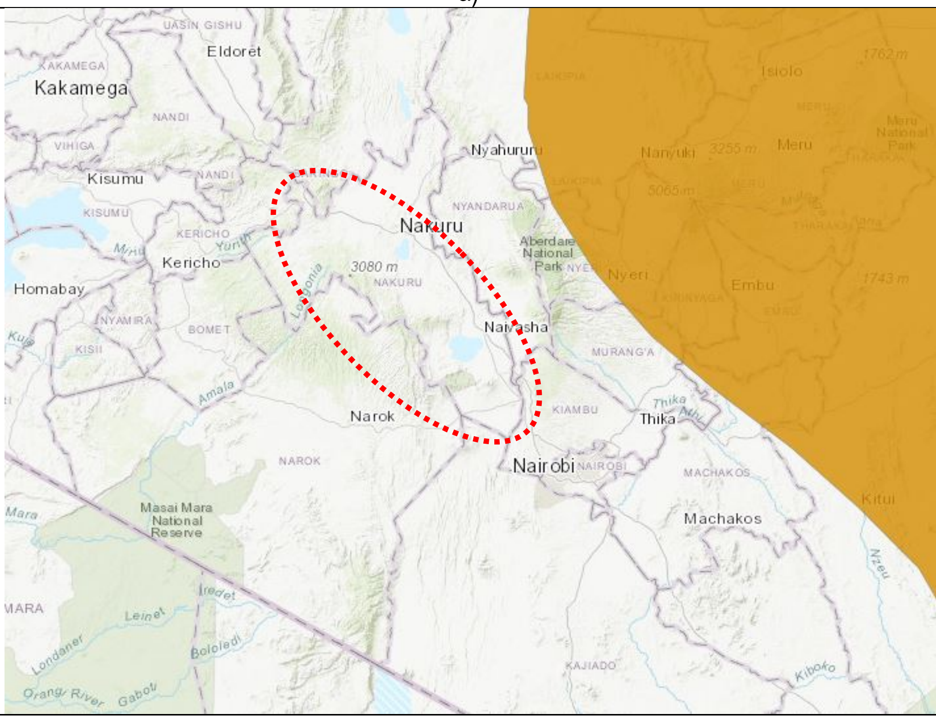


b)

Figure 16: The extant distribution range of the Grant's Wood-hoopoe (*Phoeniculus granti*) relative survey area according to (a) the Kenya Bird Map and (b) IUCN (2021). The red arrows and dashed circle show the approximate distribution limits of the survey area. The stippled arrow shows the approximate position where the species was observed during the surveys.

a)

b)

Figure 17: Grant's Wood-hoopoe (*Phoeniculus granti*) observed at Soysambu Conservancy in leleshwa woodland. Note the violet/purple hues on the head and shoulder and the complete absence of any green hues. The contrast input levels of the images were increased ("overexposing") in favour of the white spectrum to "expose" the violet hues. The images were taken with the aid of a spotting scope ("digiscoping") which explains the dark corners ("vignetting").

5.4. Species of Conservation Concern

5.4.1. Biome-restricted Species

Six major biomes are recognised in Kenya. These represent major ecological communities characterised by distinctive floristic life forms and principal plant species. Each of these has its own biome-restricted assemblage of bird species which is sensu lato endemic to a particular biome.

The concept of biome-restricted species is often used by BirdLife International to identify Important Bird Areas (IBAs) which aims to identify areas or sites of international importance for birds (Fishpool, 1997). Specific criteria are used by the BirdLife International Secretariat to identify IBAs, of which Category A3 has pertinent relevance to biome-restricted bird species. Therefore, any potential IBA should hold significant numbers of species whose distributions are largely confined to a single biome. In addition, critical habitat identification is required by the International Finance Corporation's (IFC) Performance Standard 6 to determine risks, and to avoid or mitigate impacts on areas with high biodiversity value. In terms of the critical habitat identification, Criteria 4 has relevance to unique ecosystems containing unique assemblages of species, including concentrations of biome-restricted species. Therefore, the category/criteria apply to groups of species with shared distributions greater than 50 000 km² which occur mostly in a particular biome.

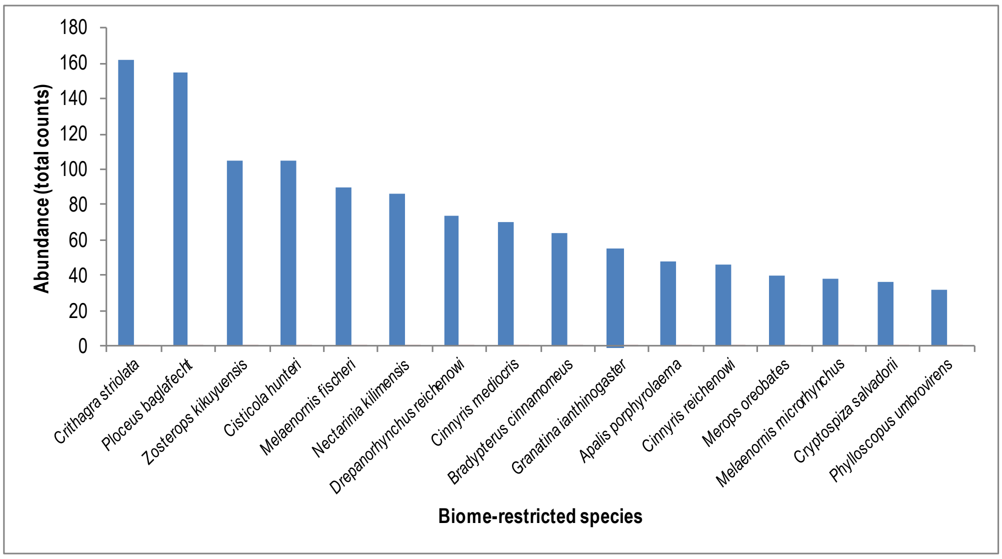
The species assemblage on the survey area has relevance to three of the major biomes in Kenya which includes the Afrotropical Highlands biome, the Somali-Masai biome and the Lake Victoria basin biome (Appendix 4 and Appendix 5):

- ***Afrotropical Highlands biome***: Approximately 50 species (of the 70 species in Kenya) restricted to the Afrotropical Highlands Biome are expected[9] to occur on the survey area, of which 44 species were confirmed. It was evident that a high number of Afrotropical Highlands Biome species are present on the survey area. These species are invariably confined to Afromontane forest and upland grassland mosaics in the Kenyan highlands.
- ***Somali-Masai biome:*** Approximately 21 species (of the 94 species in Kenya) restricted to the Somali-Masai Biome are expected to occur on the survey area, of which 17 species were confirmed. Many of these occur in arid thornveld savanna and reach their distributional limits at the survey area.
- ***Lake Victoria Basin biome:*** The Black-lored Babbler (*Turdoides sharpei*) is the only species (of nine species in Kenya) that occur on the survey area which is restricted to the Lake Victoria Basin biome.

The dominant biome-restricted assemblage is primarily confined to the Afrotropical Highland biome, with the Streaky Seedeater (*Crithagra striolata*), Baglafecht Weaver (*Ploceus baglafecht*), Kikuyu White-eye *(Zosterops kikuyuensis*) and Hunter's Cisticola (*Cisticola hunteri*) attaining the highest abundances on the survey area (Figure 18**Figure 18**). The dominant biome-restricted species with the highest frequency of occurrence is represented by the Baglafecht Weaver (*Ploceus baglafecht*) which occurs on 38 % of the point counts, followed by the Streaky Seedeater (*Crithagra striolata*) which occurs on 31 % of the point counts and the White-eyed Slaty Flycatcher (*Melaenornis fischeri*) which occurs on 26 % of the point counts (Figure 18). The Purple Grenadier (*Granatina ianthinogaster*) and the African Grey Flycatcher (*Melaenornis microrhynchus*) were the only prominent species on the survey area restricted to the Somali - Masai biome.
Species restricted to the Afrotropical Highlands biome were widespread on the survey area and present in nearly every habitat type, although peak abundance values were observed from forest-dominated habitat and upland grassland (AfmB, AUF, AfR and EWG) (Figure 19). The average abundance values was lower for bird species

[9] These species are expected to occur based on the Kenya Bird Map Project along with the availability f suitable habitat and by applying processional judgement/experience of the author.

restricted to the Somali-Masai biome, which were confined to woodland and bushland vegetation, as opposed to forest habitat types (Figure 19). The Black-lored Babbler (*Turdoides sharpei*), the only species restricted to the Lake Victoria basin Biome was prominent in riparian wooded vegetation (RWV) (Figure 19).



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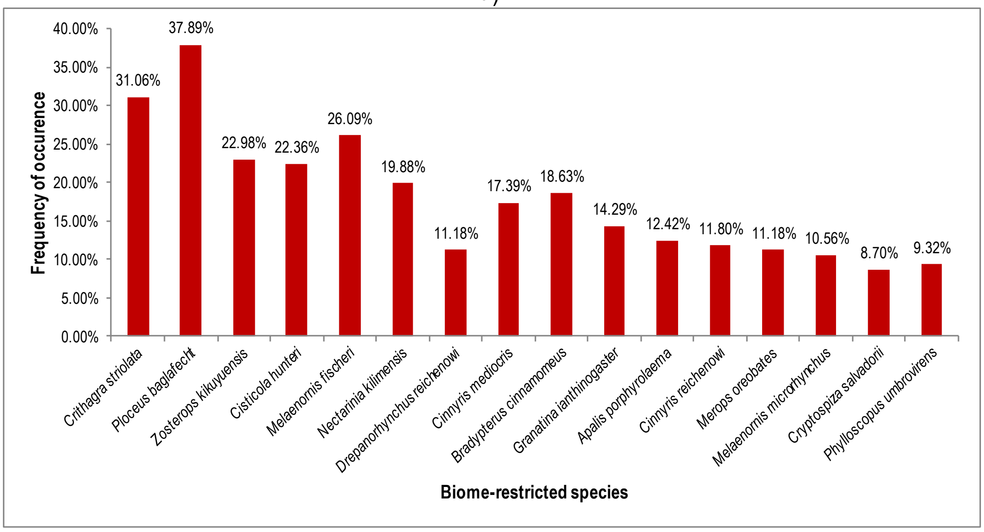


b)

Figure 18: The (a) abundance and (b) frequency of occurrence (number of sites a species was observed) of selected biome-restricted species recorded from 161 point counts (for both seasons) on the survey area.

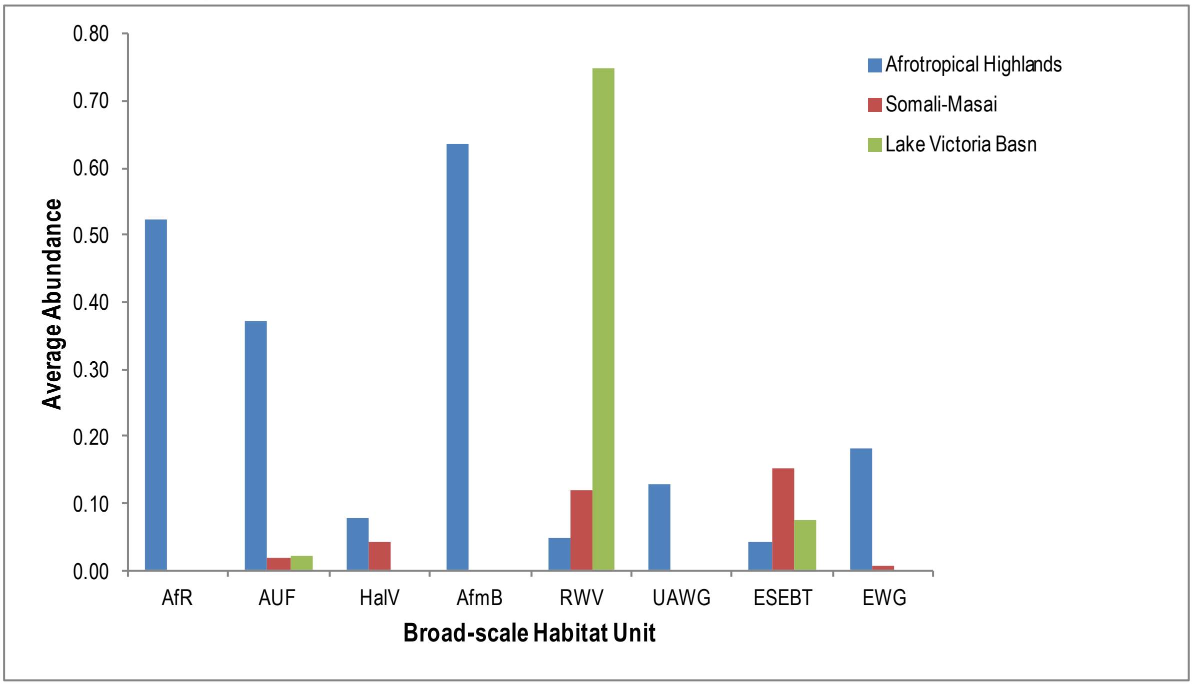


Figure 19: The distribution of biome-restricted species on broad-scale habitat units according to average abundance values (average of total counts per point count for each habitat type). Afr - Afromontane rainforest, AUF - Afromontane undifferentiated forest, HalV - Halophytic vegetation, AfmB - Afromontane bamboo, RWV - Riparian wooded vegetation, UAWG - Upper *Acacia* wooded grassland, ESEBT - Evergreen and semi-evergreen bushland and thicket and EWG - Edaphic wooded grassland.

5.4.2. Endemic Species

A total of 37 endemic bird species occurs in Kenya, of which 14 species are expected to be present on the survey area. Ten of these were observed during the two survey campaigns (see Appendix 1, Appendix 5 and Table 6).

Table 6: A summary table of the endemic species expected and observed on the survey area. KM - Kenyan mountains Endemic Bird Area, SP - Serengeti Plains Endemic Bird Area, EA - endemic to East Africa and KEN - endemic to Kenya.

Species	Common Name	Expected	Observed	Endemic Status	Habitat preference	Status on survey area
Cisticola hunteri	Hunter's Cisticola		X	KM; EA	Bracken and secondary shrub along forest edges.	Common, it occurs in 22.36% of all point counts. Most numerous in upland ESEBT, AUF and AfmB.
Crithagra buchanani	Southern Grosbeak-canary		X	EA	Dry drainage lines and arid woodland dominated by *Acacia* and *Commiphora* spp.	Peripheral to survey area (1.25%), most records from RWV.
Tauraco hartlaubi	Hartlaub's Turaco		X	EA	Afromontane forest.	It occurs in 2.48% of all point counts. Prevalent in AfR and AfmB.
Cinnyris mediocris	Eastern Double-collared Sunbird		X	EA	Bracken and secondary shrub along forest edges.	Common, it occurs in 17.39% of all point counts. Prevalent in AfR and AfmB.
Passer rufocinctus	Kenya Sparrow		X	EA	Villages, gardens, cultivation and secondary shrub at high altitudes (Kenyan highlands).	Common, most prevalent in ESEBT and EWG habitat.
Passer suahelicus	Swahili Sparrow		X	EA	Mainly near villages.	Mainly restricted to villages in close association to AUF habitat.
Euplectes jacksoni	Jackson's Widowbird		X	KM; EA	Upland grassland.	Uncommon, only recorded from one locality corresponding to EWG.
Lamprotornis hildebrandti	Hildebrandt's Starling		X	EA	Open woodland.	Uncommon, only recorded from one locality corresponding to ESEBT.
Prionops poliolophus	Grey-crested Helmetshrike		X	SP; EA	Open woodland with *Acacia* and leleshwa woodland.	Uncommon, two observations from tall Acacia woodland in Soysambu and Marula.
Zosterops kikuyuensis	Kikuyu White-eye		X	KEN; KM; EA	Afromontane forest, as well as upland woodland and gardens.	Common, it occurs in 22.98% of all point counts. Most numerous in upland ESEBT and AfR.
Macronyx sharpei	Sharpe's Longclaw	X		KEN; KM; EA	Upland tussock grassland.	Rare, probably absent. Two recent records from survey area (probably erroneous - according to Kenya Bird Map).
Melaniparus fringillinus	Red-throated Tit	X		EA	Arid Acacia woodland.	Unknown, probably irregular in arid woodland.
Scleroptila psilolaema elgonensis	Moorland (=Elgon) Francolin	X		EA	Upland tussock grassland and moorland.	Unknown, probably uncommon in upland grassland (EGW).
Poeoptera femoralis	Abbott's Starling	X		KM; EA	Afromontane rainforest and associated forest habitat.	Overlooked, probably resident in AfR and AfmB forest corresponding to the Kinale Forest block.

5.4.3. Threatened and near threatened species (IUCN, 2021)

5.4.3.1. Summary of Threatened and near threatened species on the survey area

Twenty-seven (27) threatened and near threatened species were expected to occur on the survey area and 19 species were confirmed during the dry and wet surveys (Table 7). These include invariably large-bodied birds of prey and scavenging taxa, a crane species, large terrestrial birds (bustards and ground-hornbills) as well as smaller passerines. Of the species observed, two are critically endangered (c. Rüppell's Vulture *Gyps rueppelli* and African White-backed Vulture *Gyps africanus*), five are endangered (c. Steppe Eagle *Aquila nipalensis*, Martial Eagle *Polemaetus bellicosus*, Bateleur *Terathopius ecaudatus*, Grey Crowned Crane *Balearica regulorum,* Secretarybird *Sagittarius serpentarius*), three are vulnerable (c. Tawny Eagle *Aquila rapax*, Southern Ground Hornbill *Bucorvus leadbeateri* and Sooty Falcon *Falco concolor*) and nine are near threatened (c. Crowned Eagle *Stephanoaetus coronatus*, Pallid Harrier *Circus macrourus,* Lesser Flamingo *Phoeniconaias minor*, Curlew Sandpiper *Calidris ferruginea*, Chestnut-banded Plover *Charadrius pallidus*, Mountain Buzzard *Buteo oreophilus*, Grey-crested Helmetshrike *Prionops poliolophus*, Jackson's Widowbird *Euplectes jacksoni* and Kori Bustard *Ardeotis kori*).

Four of the species (c. Rüppell's Vultures *Gyps rueppelli*, African White-backed Vulture *G. africanus*, Tawny Eagle *Aquila rapax* and Bateleur *Terathopius ecaudatus*) are scavengers and occur over large surface areas in search of carcasses and were in most instances observed on the survey area within conservancies where game species were prominent (Figure 20). The habitat requirements of these species are unspecialised, which explain why they occur in almost any habitat that is dominated by woodland or bushland (they were absent in forests).

The Steppe Eagle (*Aquila nipalensis*), Sooty Falcon (*Falco concolor*) and Pallid Harrier (*Circus macrourus*) are non-breeding Palearctic migrants to the area (Figure 21). The Crowned Eagle (*Stephanoaetus coronatus*), Secretarybird (*Sagittarius serpentarius*) and Martial Eagle *Polemaetus bellicosus*) are sedentary, with the former is restricted to forest habitat and riparian wooded vegetation (Figure 21 and Figure 22). An active nest of a Crowned Eagle pair is also located on the Soysambu Conservancy in riparian wooded vegetation (Figure 21). The Secretarybird appears to be a fairly common resident of the open ESEBT habitat located within the conservancies. The near threatened Mountain Buzzard (*Buteo oreophilus*) were prominent in intact AfR , AUF and AfmB forests, especially the Kinale Forest block (Figure 21).

Two other large terrestrial species also occur, with at least two to three groups of Southern Ground-hornbill (*Bucorvus leadbeateri*) present in the conservancies, while Kori Bustard (*Ardeotis kori*) was recorded from open ESEBT habitat along the A8 South highway (Figure 22).

The endangered Grey Crowned Crane (*Balearica regulorum*) were prominent on the survey area, and often observed in large foraging and displaying flocks on cultivated land in Marula Estates. However, pairs were also observed from wetland features in Marula Estates, some of the EWG wetland sites and at the Mangou Pond, thereby suggesting that this species also breeds within the survey area (Figure 22).

The Jackson's Widowbird (*Euplectes jacksoni*) was uncommon on the survey area and only recorded at a single EWG site consisting of a seep wetland surrounded by moist grassland on the northern part of the survey area (Figure 23). The Grey-crested Helmetshrike (*Prionops poliolophus)* was also uncommon and only observed from two localities corresponding to tall *Acacia xanthophloea* woodland at Soysambu Conservancy and from Leleshwa woodland at Marula Estates (Figure 23).

The remaining species (Lesser Flamingo *Phoeniconaias minor*, Curlew Sandpiper *Calidris ferruginea*, Chestnut-banded Plover (*Charadrius pallidus*) consists of water- and shorebird taxa and were only observed from halophytic habitat along the shoreline of Lake Elmenteita. However, significant numbers of Lesser Flamingo and Curlew Sandpiper were present along the shoreline of Lake Elmenteita, which is an important staging ("fuelling") site for migrating Palearctic wader and shorebird species (Figure 24).

Table 7: Threatened and near threatened bird species that could utilise the proposed survey area based on their known (extant) and historical distribution ranges and the presence of suitable habitat. Conservation categories

were used according to the IUCN (2021). Species highlighted in grey were confirmed during the surveys of February 2021 and April 2021.

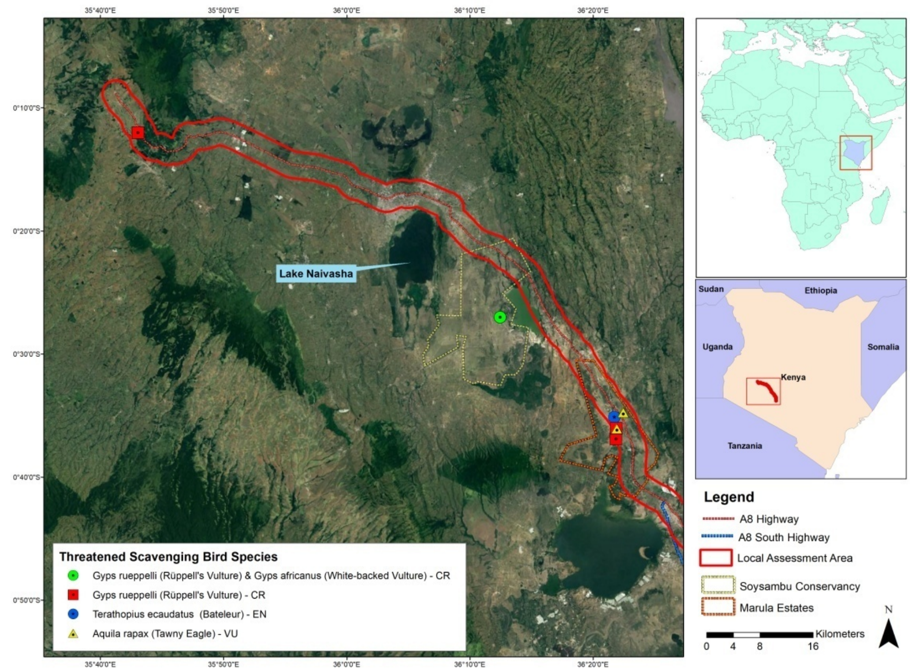
Family	Scientific Name	Common Name	Conservation Status	Number of individuals observed	Preferred Habitat Type	Observed Habitat Type	Primary Trophic Guild
Accipitridae	*Gyps africanus*	White-backed Vulture	Critically Endangered	Approximately 5-10, on carcass at Soysambu Conservancy.	Breeds on tall, flat-topped trees. Mainly restricted to large rural or extensive bushland with game or free-roaming livestock.	ESEBT	Scavenger
Accipitridae	*Necrosyrtes monachus*	Hooded Vulture	Critically endangered	None.	Lowland savanna, often commensal with human settlements. Considered to be a highly irregular foraging visitor to the survey area.	N/a	Scavenger
Accipitridae	*Gyps rueppelli*	Rüppell's Vulture	Critically endangered	Approximately 20 feeding on carcass at Soysambu Conservancy. Several individuals observed overhead at Marula Estates.	Widespread albeit partial to conservancies with game.	ESEBT, RWV	Scavenger
Accipitridae	*Neophron percnopterus*	Egyptian Vulture	Endangered	None.	Rare in the area and probably represented by irregular foraging individuals.	N/a	Scavenger
Accipitridae	*Torgos tracheliotos*	Lappet-faced Vulture	Endangered	None.	An infrequent foraging visitor, probably only present on conservancies.	N/a	Scavenger
Accipitridae	*Aquila nipalensis*	Steppe Eagle	Endangered	Two observations of birds perched on a powerline at Marua Estates (February) and migrating birds (two individuals) along ESEBT habitat near the A8 South Highway.	Open woodland and savanna.	ESEBT	Insectivore: ground gleaner - primarily termites
Accipitridae	*Aquila heliaca*	Eastern Imperial Eagle	Vulnerable	None.	Open woodland and savanna along mountain ranges. Rare in survey area, probably individuals on passage (during migration).	N/a	Carnivore: ground hawker

Family	Scientific Name	Common Name	Conservation Status	Number of individuals observed	Preferred Habitat Type	Observed Habitat Type	Primary Trophic Guild
Accipitridae	*Clanga clanga*	Great Spotted Eagle	Vulnerable	None.	Open woodland and savanna along mountain ranges. Birds on the survey area are probably individuals on passage (during migration).	N/a	Insectivore: ground gleaner
Accipitridae	*Polemaetus bellicosus*	Martial Eagle	Endangered	One observation of a single individual during February at Marula Estates.	Extensive woodland and savanna, also open wooded grassland.	ESEBT	Carnivore: ground hawker
Accipitridae	*Terathopius ecaudatus*	Bateleur	Endangered	One observation of two birds during February 2021 on Marula Estates.	Extensive woodland and savanna, also open wooded grassland.	ESEBT	Scavenger
Accipitridae	*Circus macrourus*	Pallid Harrier	Near threatened	One observation of a pair during February 2021 and another observation west of Nakuru town.	Mainly open grassy woodland and floodplains.	ESEBT	Insectivore: ground gleaner
Accipitridae	*Stephanoaetus coronatus*	Crowned Eagle	Near threatened	Three independent observations from riparian wooded vegetation at Soysambu Conservancy and from the Kinale Forest. An active nest occurs at Soysambu Conservancy in RWV.	Confined to forest or dense mesic woodland.	AUF, AfR and RWV	Carnivore: arboreal hawker - specialist primate hunter
Accipitridae	*Aquila rapax*	Tawny Eagle	Vulnerable	Three observations of birds observed at Marula Estates and along the A8 South Highway. A pair was observed roosting and mating on powerline pylons at Marula Estates.	Extensive woodland and savanna, also open wooded grassland.	ESEBT	Scavenger
Accipitridae	*Buteo oreophilus*	Mountain Buzzard	Vulnerable	Five observations from birds (mainly pairs) over forest habitat. Abundant in Kinale Forest.	Mainly forest	AUF, AfR, AfmB	Carnivore: ground hawker
Accipitridae	*Gypaetus barbatus*	Bearded Vulture	Near threatened	None.	Varied, mainly high altitude grassland in mountainous areas. Regarded as a highly irregular foraging visitor to UAWG and EWG.	N/a	Scavenger, mainly bone marrow

Family	Scientific Name	Common Name	Conservation Status	Number of individuals observed	Preferred Habitat Type	Observed Habitat Type	Primary Trophic Guild
Acrocephalidae	*Acrocephalus griseldis*	Basra Reed Warbler	Endangered	None.	Confined to reedbeds and dense tangled vegetation in close proximity EGW and HalV. Known to be present during the austral summer at Lakes Nakuru and Naivasha. Could be associated with HalV habitat near lakes on survey area.	N/a	Insectivore: lower canopy foliage gleaner
Ardeidae	*Ardeola idae*	Malagasy Pond Heron	Endangered	None, although yearly present in HalV habitat at Lake Elmenteita during the austral dry season.	Confined to dense marginal vegetation around freshwater lakes, ponds and pools. Possibly a regular non-breeding foraging visitor during the austral dry season to freshwater systems near Lake Elmenteita and potentially also Manguo Pond.	HalV	Carnivore: Freshwater forager
Bucorvidae	*Bucorvus leadbeateri*	Southern Ground Hornbill	Vulnerable	Observed at Soysambu Conservancy with at least two groups consisting of four individuals. Also observed at Marula Estates with three individuals.	Confined to open savannoid woodland and open savanna.	ESEBT	Carnivore: Ground hawker
Charadriidae	*Charadrius pallidus*	Chestnut-banded Plover	Near threatened	Single bird observed along the shoreline of Lake Elmenteita during April 2021. Probably overlooked.	Large saline lakes and saltworks.	HalV	Insectivore: Freshwater forager
Falconidae	*Falco concolor*	Sooty Falcon	Vulnerable	A pair observed overhead during April 2021 at Soysambu Conservancy.	Varied, mainly savanna. An irregular non-breeding visitor or passage migrant.	ESEBT	Carnivore: Air hawker

Family	Scientific Name	Common Name	Conservation Status	Number of individuals observed	Preferred Habitat Type	Observed Habitat Type	Primary Trophic Guild
Gruidae	*Balearica regulorum*	Grey Crowned Crane	Endangered	Several observations of pairs and large feeding flocks (>80 individuals) from various localities, Prominent in cultivated land on Marula Estates and at Manguo Pond.	Varies, mainly confined to grassland adjacent to upland wetland systems (during breeding) as well as cultivated land (during foraging).	ESEBT, EWG	Omnivore: Ground Hawker
Motacillidae	*Macronyx sharpei*	Sharpe's Longclaw	Endangered	None, recent observations (according to the Kenya Bird Map) from EWG habitat in the south near Thika-Mango flyover region). These observations require vetting as this species is often confused with Yellow-throated Longclaw (*M. croceus*).	Upland slightly grazed tussock grassland. Not observed on survey area and regarded as highly irregular owing to the degraded condition of EWG habitat and persistent trampling and disturbances caused by livestock and human-induced activities (e.g. agriculture).	N/a	Insectivore: Ground Hawker
Otididae	*Ardeotis kori*	Kori Bustard	Near threatened	At least two observations of foraging individuals in open ESEBT habitat along the A8 South Highway.	Open savannoid woodland and open savanna.	ESEBT	Carnivore: Ground Hawker
Phoenicopteridae	*Phoeniconaias minor*	Lesser Flamingo	Near threatened	Thousands (>1000 individuals) of foraging individuals along the shoreline of Lake Elmenteita.	Large saline lakes, dams and pans.	HalV	Specialist feeder of cyanobacteria
Ploceidae	*Euplectes jacksoni*	Jackson's Widowbird	Near threatened	Single observation of one male and seven females during April 2021.	Moist grassland bordering EWG habitat.	EWG	Granivore: lower canopy to ground gleaner
Sagittariidae	*Sagittarius serpentarius*	Secretarybird	Endangered	Several individuals (c. seven observations) observed foraging in Marula Estates and Soysambu Conservancy during April and February 2021.	Open savannoid grassland and open savanna.	ESEBT	Carnivore: Ground Hawker
Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper	Near threatened	Large numbers (>50 individuals) foraging along muddy shoreline habitat of Lake Elmenteita.	Mudflats along large inland lakes, dams and pans. A regular and abundant summer foraging visitor to Lake Elmenteita.	HalV	Insectivore: Freshwater forager

Family	Scientific Name	Common Name	Conservation Status	Number of individuals observed	Preferred Habitat Type	Observed Habitat Type	Primary Trophic Guild
Scolopacidae	*Gallinago media*	Great Snipe	Near threatened	None.	Dense inundated grassland along wetland systems (unchannelled seeps). Probably an uncommon summer foraging visitor to certain upland wetland systems, most notably Mangou Pond.	EWG	Insectivore: Freshwater forager
Scolopacidae	*Limosa limosa*	Black-tailed Godwit	Near threatened	None.	Open muddy shoreline along the Rift Valley lakes. Probably a regular summer foraging visitor to the shoreline of Lake Elmenteita and Lake Nakuru.	HalV	Insectivore: Freshwater forager
Scolopacidae	*Numenius arquata*	Eurasian Curlew	Near threatened	None.	Open muddy shoreline along the Rift Valley lakes. Probably an irregular summer foraging visitor to the shoreline of Lake Elmenteita.	HalV	Insectivore: Freshwater forager
Sturnidae	*Poeoptera femoralis*	Abbott's Starling	Vulnerable	None.	Afromontane Rainforest, present in the Kinale Forest block.	N/a	Frugivore: upper canopy gleaner
Vangidae	*Prionops poliolophus*	Grey-crested Helmetshrike	Near threatened	Two observations of small foraging flocks at Marula Estate (February 2021) and Soysambu Conservancy near the shoreline of Lake Elmenteita (April 2021).	*Acacia* woodland and Leleshwa woodland.	ESEBT	Insectivore: Upper canopy foliage gleaner



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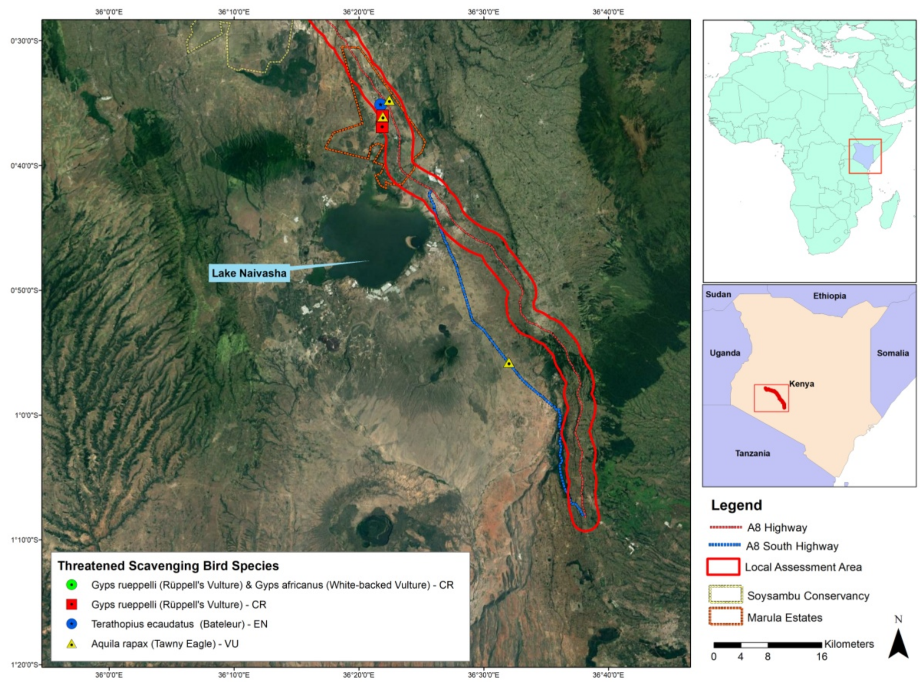

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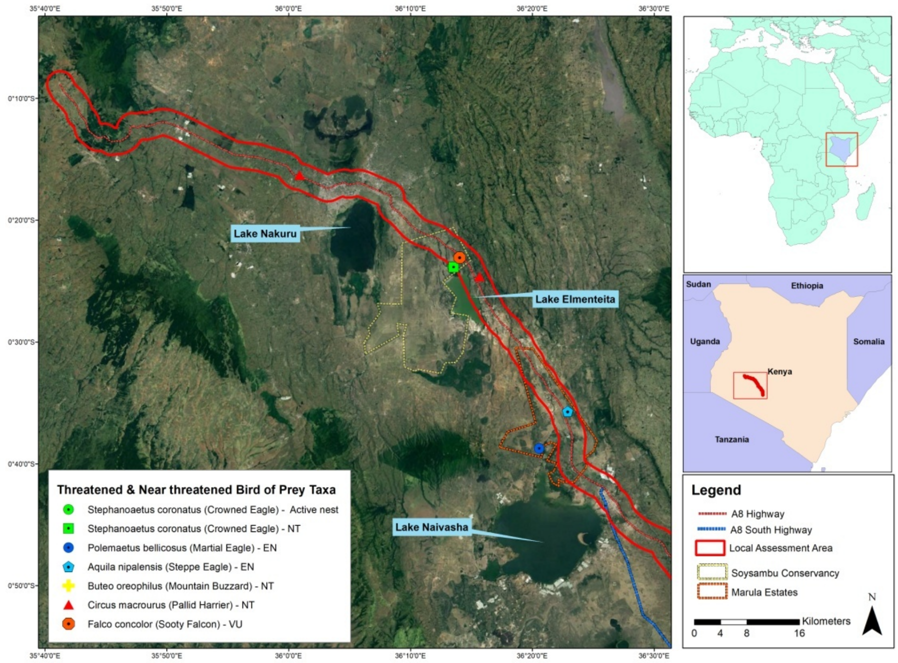
Figure 20: The occurrence (according to observations) for scavenging bird of prey taxa of the genera *Gyps*, *Terathopius* and *Aquila* on the survey area. (a) - Northern part survey area and (b) - southern part of survey area.



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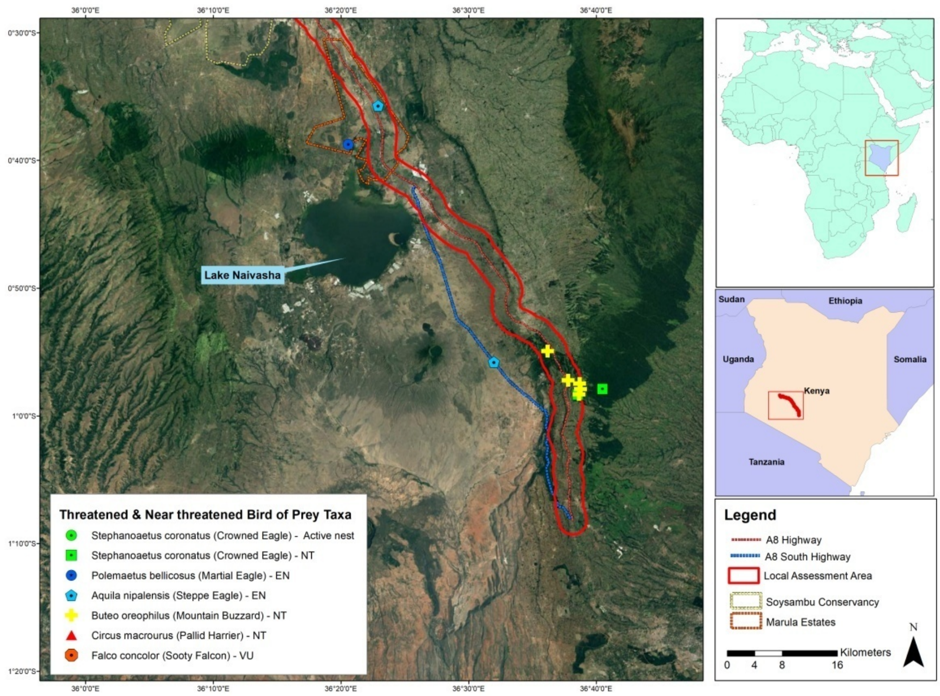

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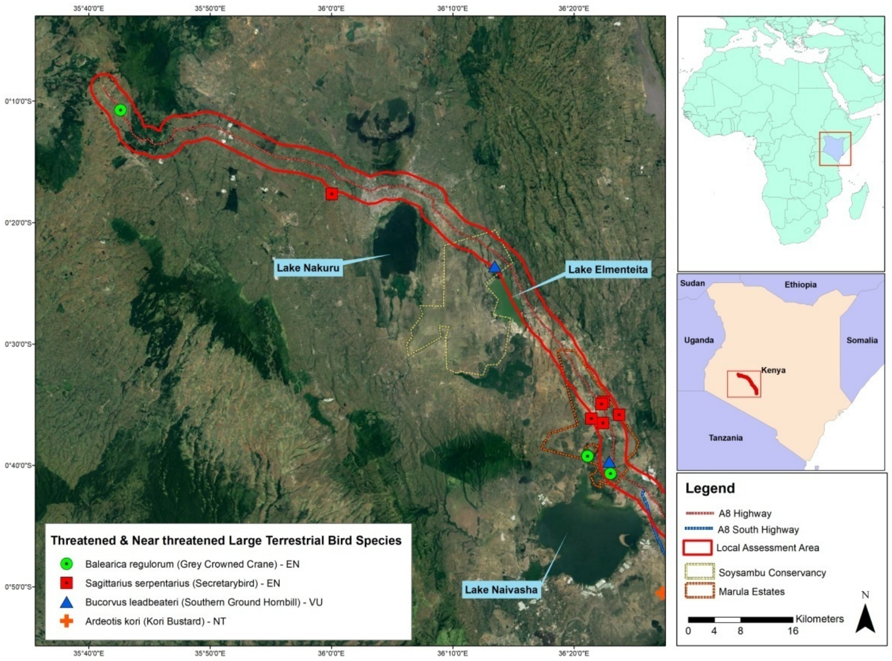
Figure 21: The occurrence (according to observations) for threatened and near threatened bird of prey species on the survey area. (a) **-** Northern part of survey area and (b) **-** southern part of survey area.



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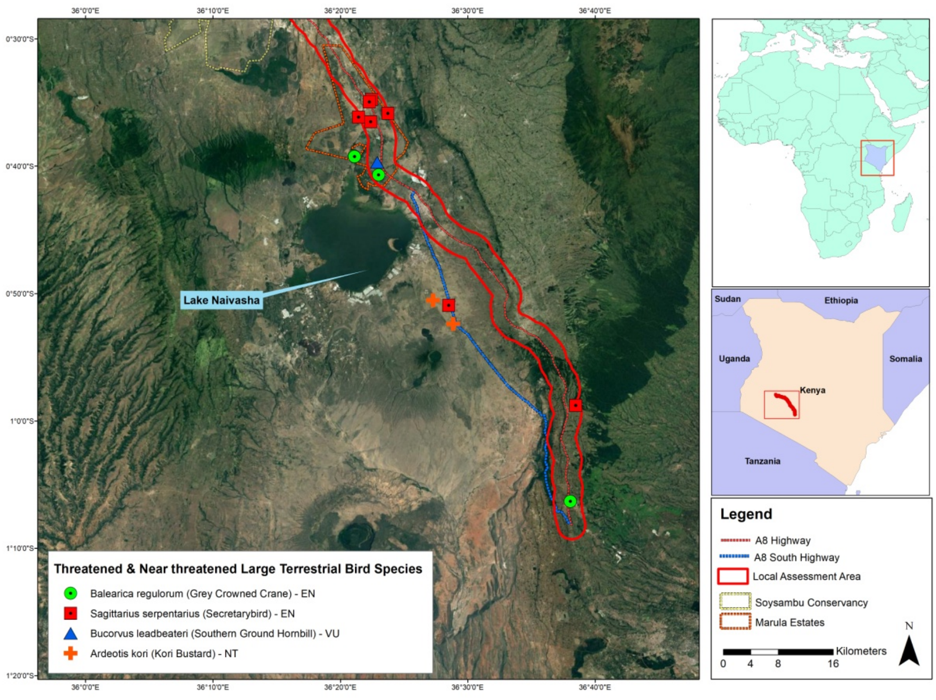

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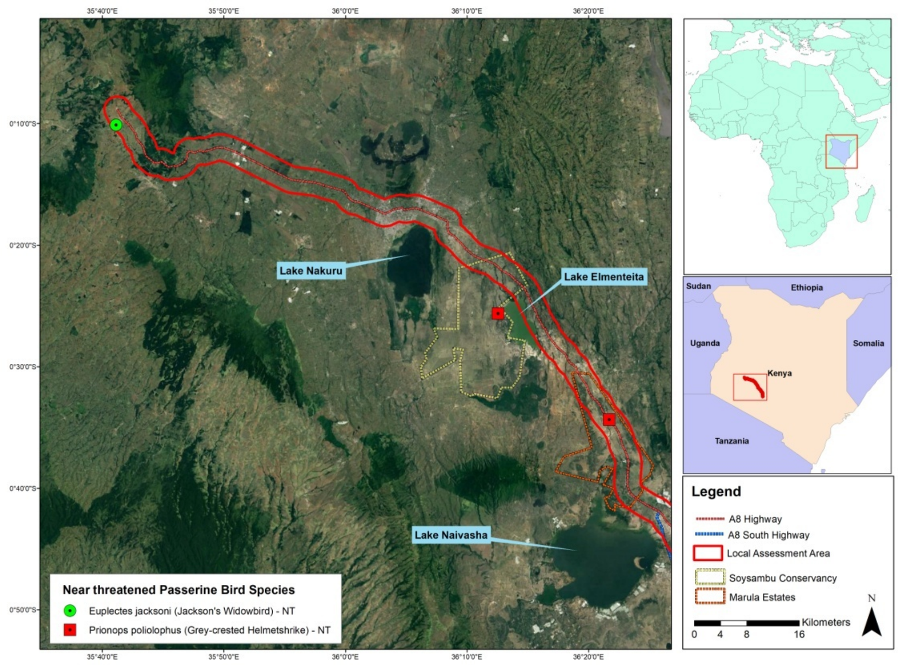
Figure 22: The occurrence (according to observations) for threatened and near threatened large terrestrial bird species of the genera *Balearica, Sagittarius, Bucorvus* and *Ardeotis* on the survey area. (a) **-** Northern part of survey area and (b) **-** southern part of survey area.



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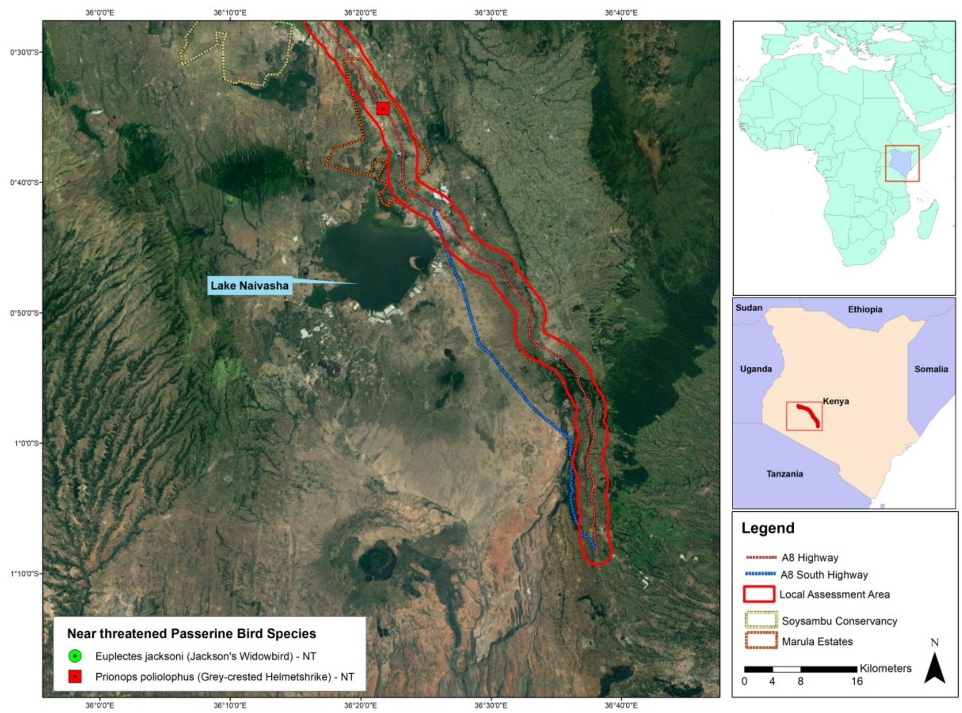


b)

Figure 23: The occurrence (according to observations) for the near threatened Jackson's Widowbird (*Euplectes jacksoni*) and Grey-crested Helmetshrike (*Prionops poliolophus*) on the survey area. (a) **-** Northern part of survey area and (b) **-** southern part of survey area.

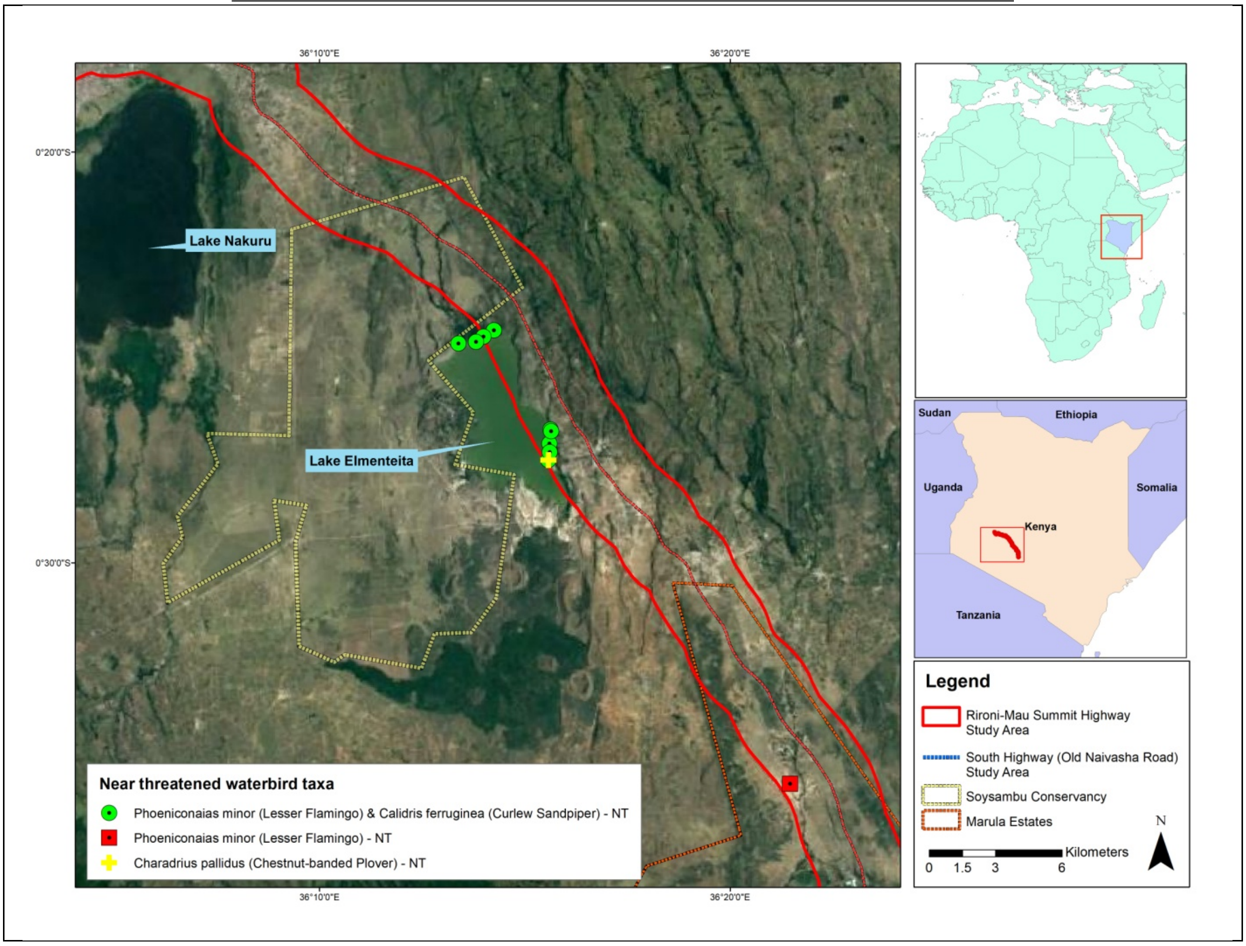


Figure 24: The occurrence (according to observations) for the near threatened Lesser Flamingo (*Phoeniconaias minor*), Curlew Sandpiper (*Calidris ferruginea*) and Chestnut-banded Plover (*Charadrius pallidus*) on the survey area.

5.4.4. Kenyan Protected Bird Species

Schedule 6 of the Wildlife Conservation and Management Act, 2013 provides a list of threatened and protected bird species that occur in Kenya. The listed threatened species are regarded as outdated since the conservation categories of many of these birds have changed during recent conservation assessments (IUCN, 2021). However, it also provides a list of species that are protected in the country. Seventeen (17) protected bird species are expected to be present on the study site, of which 12 species were observed during the survey campaigns. These include mainly iconic birds of prey (eagles), large wading birds (herons, storks and cranes), waterbirds (darters) and smaller bird taxa such as the Nyanza Swift (*Apus niansae*), Red-billed Oxpecker (*Buphagus erythrorynchus*), Kenya Sparrow (*Passer rufocinctus*) and Baillon's Crake (*Zapornia pusilla*).

5.5. Bird assemblage structure and composition: Un-altered point count data

5.5.1. Summary of point data

A total of 320 bird species and 7, 898 individuals were recorded from 161 bird point counts (for both wet and dry seasons). A mean of 18.0 species and 49.0 individuals were recorded per point count. The highest number of species was 49 species per point count (c. an AUF site along a perennial stream) and the lowest was two species (c. an EWG site at the Thika-Mango flyover). The highest number of individuals recorded per point count was 875 individuals (c. the Manguo pond), and the lowest was four individuals (an EWG site at the Thika-Mango flyover). The mean frequency of occurrence of a bird species was 5.64% and the median was 2.48%, while the most common value (mode) was 0.62%. The latter represents those species that were encountered in only one point count. Only one species occurred in more than 50% of all the point counts and nine species occurred in more than 30% of all the point counts (Table 8).

Table 8: The bird species (from 161 species counted) with a frequency of occurrence greater than 30%, observed in the survey area.

Species	Frequency (%)	Species	Frequency (%)
Pycnonotus tricolor (Dark-capped Bulbul)	65.84%	*Ploceus baglafecht* (Baglafecht Weaver)	37.89%
Camaroptera brevicaudata (Grey-backed Camaroptera)	46.58%	*Uraeginthus bengalus* (Red-cheeked Cordon-bleu)	32.30%
Cisticola chiniana (Rattling Cisticola)	40.99%	*Cossypha caffra* (Cape Robin-chat)	31.68%
Laniarius major (Tropical Boubou)	40.99%	*Crithagra striolata* (Streaky Seedeater)	31.06%
Cinnyris venustus (Variable Sunbird)	39.13%		

5.5.2. Dominance and typical species

The dominant (typical) species on the survey area are presented in Table 9. Only those species that cumulatively contributed to more than 90% to the overall similarity are presented.

The three typical bird species with the highest frequency of occurrence on the survey area include the Dark-capped Bulbul (*Pycnonotus tricolor*), Grey-backed Camaroptera (*Camaroptera brevicaudata*) and Rattling Cisticola (*Cisticola chiniana*). The typical species forms part of nearly every bird assemblage and habitat unit and are considered widespread species on the survey area. The majority of these species are insensitive to habitat type and structure and are recorded from most of the habitat types on the survey area. Approximately 55 % of the typical species are insectivorous (either in the lower or upper canopy) and 25% are granivores (feeding on seeds), while the remaining composition includes small frugivores (consuming small sized fruit) and facultative nectarivores (sunbirds). Five (25%) of the typical species are restricted to the Afrotropical Highlands biome.

Table 9: Typical bird species on the survey area. * - species restricted to the Afrotropical Highlands Biome.

Species	Average abundance	Consistency	% Contribution	Primary Trophic Guild
Pycnonotus tricolor (Dark-capped Bulbul)	1.3	0.78	14.38	Frugivore: upper canopy gleaner
Camaroptera brevicaudata (Grey-backed Camaroptera)	0.75	0.49	6.31	Insectivore: lower canopy foliage gleaner
Cisticola chiniana (Rattling Cisticola)	0.98	0.41	5.83	Insectivore: upper canopy foliage gleaner
Laniarius major (Tropical Boubou)	0.84	0.42	5.48	Insectivore: lower canopy foliage gleaner
Cinnyris venustus (Variable Sunbird)	0.81	0.39	5.2	Nectarivore
Ploceus baglafecht (Baglafecht Weaver)*	0.96	0.37	4.96	Granivore: Lower to upper canopy gleaner
Crithagra striolata (Streaky Seedeater)*	1.01	0.29	3.59	Granivore: Lower to upper canopy gleaner
Uraeginthus bengalus (Red-cheeked Cordon-bleu)	0.82	0.31	3.45	Granivore: Ground to undergrowth gleaner
Cossypha caffra (Cape Robin-chat)	0.43	0.31	3.28	Insectivore: lower canopy foliage gleaner
Apalis flavida (Yellow-breasted Apalis)	0.53	0.26	2.22	Insectivore: upper canopy foliage gleaner
Serinus flavivertex (Yellow-crowned Canary)	0.61	0.21	2	Granivore: upper canopy gleaner
Cisticola hunteri (Hunter's Cisticola)*	0.65	0.21	1.91	Insectivore: upper canopy foliage gleaner
Phylloscopus trochilus (Willow Warbler)	0.68	0.27	1.89	Insectivore: upper canopy foliage

Species	Average abundance	Consistency	% Contribution	Primary Trophic Guild
				gleaner
Melaenornis fischeri (White-eyed Slaty Flycatcher)*	0.56	0.25	1.84	Insectivore: air hawker under canopy
Prinia subflava (Tawny-flanked Prinia)	0.5	0.24	1.77	Insectivore: upper canopy foliage gleaner
Zosterops kikuyuensis (Kikuyu White-eye)*	0.65	0.23	1.63	Insectivore: upper canopy foliage gleaner
Chalcomitra senegalensis (Scarlet-chested Sunbird)	0.39	0.24	1.61	Nectarivore
Turdus abyssinicus (Abyssinian Thrush)	0.89	0.23	1.55	Frugivore: upper canopy gleaner
Streptopelia capicola (Ring-necked Dove)	0.44	0.22	1.34	Granivore: ground gleaner
Terpsiphone viridis (African Paradise-flycatcher)	0.3	0.22	1.24	Insectivore: air hawker under canopy

5.5.3. Dominant assemblage structure and composition

Multidimensional scaling and hierarchical agglomerative clustering ordination of relative bird abundance values obtained from 161 point counts showed that the bird compositions on forest habitat types (AfR, AUF and AfmB) and edaphic wooded grassland habitat (EWG) are significantly different from each other, and also from woodland and bushveld habitat types (ESEBT, RWV and UAWG) (ANOSIM Global R=0.368, p=0.01) (Figure 25 and Table 10). However, the bird compositions pertaining to the different wooded and bushland habitat units (e.g. ESEBT, UAWG and RWV) were indifferent from each other with a high overlap in species. The Halophytic vegetation (HalV) also share many species that are commonly encountered in woodland habitat, and was also not significantly different from the wooded and bushland habitat units. From the ordination it is evident that the upper *Acacia* wooded grassland (UAWG) and halophytic vegetation (HalV) units form an ecotonal habitat between the forest and woodland units.

Evidently, the survey area consists of three broad bird associations, which consists of an (1) association dominated by forest-dependant bird species, an (2) association dominated by typical woodland birds and (3) an association consisting of species with high affinities for open grassland and wetland habitat.

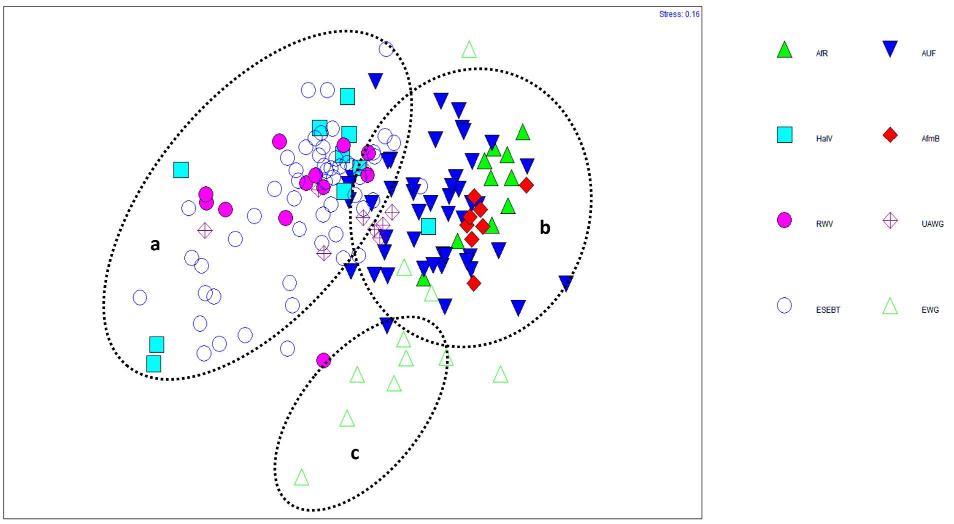


Figure 25: A two-dimensional non-metric multidimensional scaling ordination of the relative abundances of bird species based on Bray-Curtis similarities obtained from 161 point counts (stress = 0.16). (a) - a homogenous bird association pertaining to woodland and shrubland habitat b - (a) an association pertaining to predominantly forest birds and (c) - an association consisting of grassland and wetland bird species.

Table 10: A pairwise ANOSIM test between Bray-Curtis similarity coefficients of bird count data obtained from eight broad-scale habitat types. Significant differences are highlighted in yellow.

Pairwise test	R statistic	*P* value	Significance
AfR, AUF	0.126	7.3	Not significant
AfR, HalV	0.646	0.1	Significant
AfR, AfmB	0.137	5.3	Not significant
AfR, RWV	0.794	0.1	Significant
AfR, UAWG	0.781	0.1	Significant
AfR, ESEBT	0.607	0.1	Significant
AfR, EWG	0.674	0.1	Significant
AUF, HalV	0.459	0.1	Significant
AUF, AfmB	-0.137	91.3	Not significant
AUF, RWV	0.555	0.1	Significant
AUF, UAWG	0.148	6.8	Not significant
AUF, ESEBT	0.405	0.1	Significant
AUF, EWG	0.587	0.1	Significant
HalV, AfmB	0.615	0.2	Significant
HalV, RWV	0.151	1.8	Not significant
HalV, UAWG	0.232	0.7	Not significant
HalV, ESEBT	0.12	9.7	Not significant
HalV, EWG	0.578	0.1	Significant
AfmB, RWV	0.808	0.1	Significant
AfmB, UAWG	0.766	0.1	Significant
AfmB, ESEBT	0.586	0.1	Significant
AfmB, EWG	0.522	0.1	Significant
RWV, UAWG	0.301	0.2	Not significant
RWV, ESEBT	0.054	26.8	Not significant
RWV, EWG	0.69	0.1	Not significant
UAWG, ESEBT	-0.039	60.7	Not significant
UAWG, EWG	0.532	0.1	Significant
ESEBT, EWG	0.666	0.1	Significant

5.5.4. Dominant Guilds

An analysis of the primary tropic guilds of the bird species composition on survey area shows that 24.5% of the species composition consists of herbivores. The high number of herbivores is contributed by congregations of plant-eating Anatid (ducks and geese) species which were confined to wetlands (EWG - e.g. Manguo Pond) and areas of inundated halophytic vegetation (e.g. the Rift Valley lakes). More than 19% of the species composition is also composed of nectarivores (sunbird species) and a high diversity of granivores (mainly Ploceid weavers, Euplectine widowbird, waxbills and finches). In addition, between 10 and 12% of the species composition on the survey area consists of insectivores (predominantly bird species that prey on insects and invertebrates) and frugivores (fruit-eating birds). Carnivores were represented by the least abundant guild, which includes birds of prey, varius kingfishers and rollers (Figure 26).

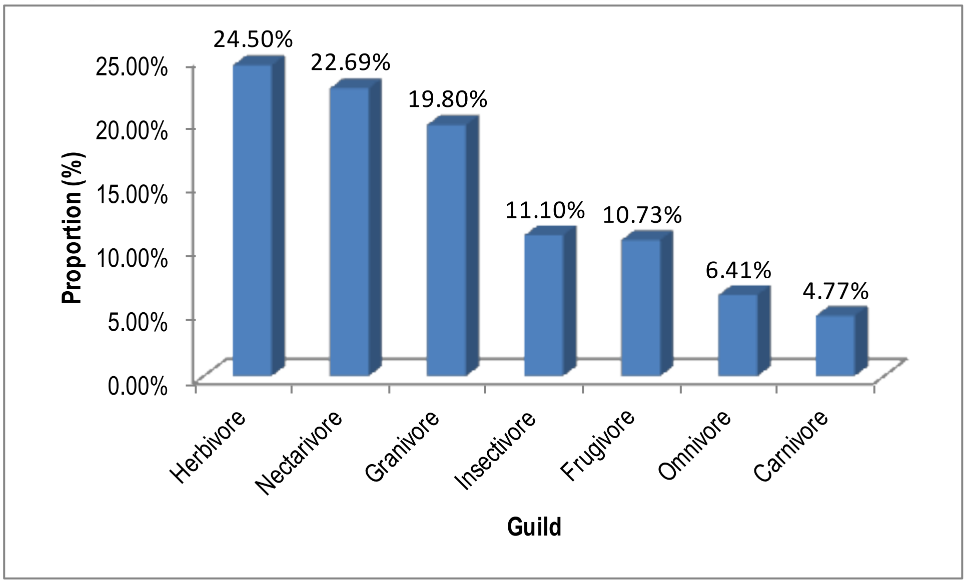


Figure 26: The proportion (%) of the bird species composition consisting of primary trophic guilds observed from 161 point counts on the survey area.

An analysis of each primary guild, according to foraging strategy (secondary guilds) shows that ground hawkers (shrikes, kingfishers) are prominent carnivore guild, followed by freshwater foragers (herons, cormorants and certain stork taxa) and arboreal hawkers (e.g. mainly medium to small bodied sparrowhawks of the genus *Accipiter*). Air hawkers such as certain falcons were uncommon on the survey area (Figure 27). Omnivores were represented by ground hawkers (taking food items from the ground) included taxa such as crows (genus *Corvus*), Marabou Storks (*Leptoptilos crumeniferus*) and Grey Crowned Crane (*Balearica regulorum*).

An analysis of the foraging strategies used by frugivore, herbivore and granivore species shows that the highest proportion of birds were represented by small-bodied granivores (mainly waxbills, canaries, weavers and widowbirds) which feed on the ground, as well as the lower and the upper strata (Figure 28). The highest proportion of herbivores includes freshwater foragers (mainly duck and geese species and certain rallid taxa such as swamphens and coots), while the highest proportion of frugivores occurs in the upper canopy (e.g. hornbills, turacos, mousebirds, greenbuls and barbets) (Figure 28). Frugivores of the lower canopy were uncommon, and included specialist forest doves (mainly Lemon Dove *Columba larvata*).

The highest proportion of insectivorous species consists of air hawkers which feed under the canopy (e.g. flycatchers in forest habitat), lower canopy foliage gleaners and upper canopy foliage gleaners (represented by a diversity of small passerines of the Cisticolidae, Sylviidae, Muscicapidae and Malaconotidae) (Figure 29). Specialised insectivores occur at intermediate abundances and are represented by the probers (bark excavators such as woodpeckers), bark cleaners (e.g. wood hoopoes) and freshwater foragers (Palearctic waders and shorebird taxa). Rare or uncommon insectivorous guilds are represented by honeyguides (which feed primarily on beeswax) and oxpeckers (genus *Buphagus*) which are dependent on game species (Figure 29**Error! Reference source not found.**).

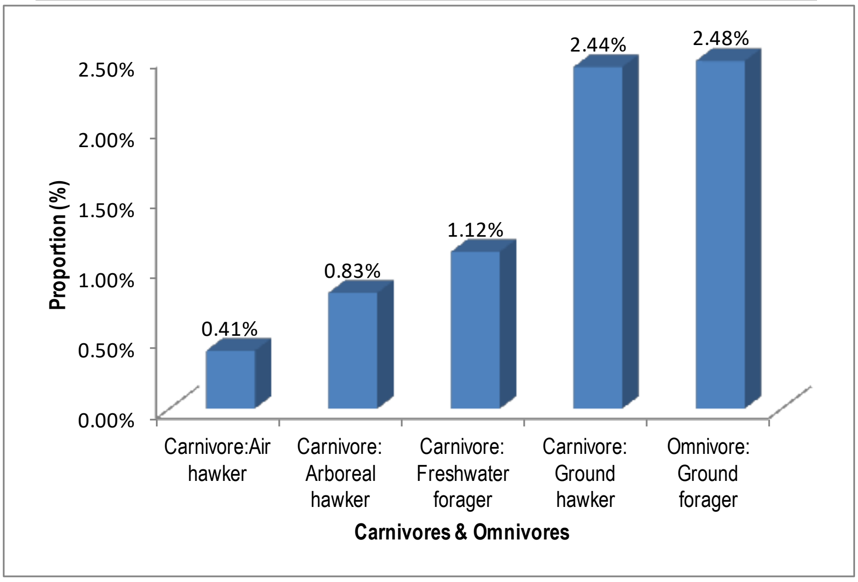


Figure 27: The proportion (%) of the bird species composition utilised by carnivore and omnivore bird species on the survey area.

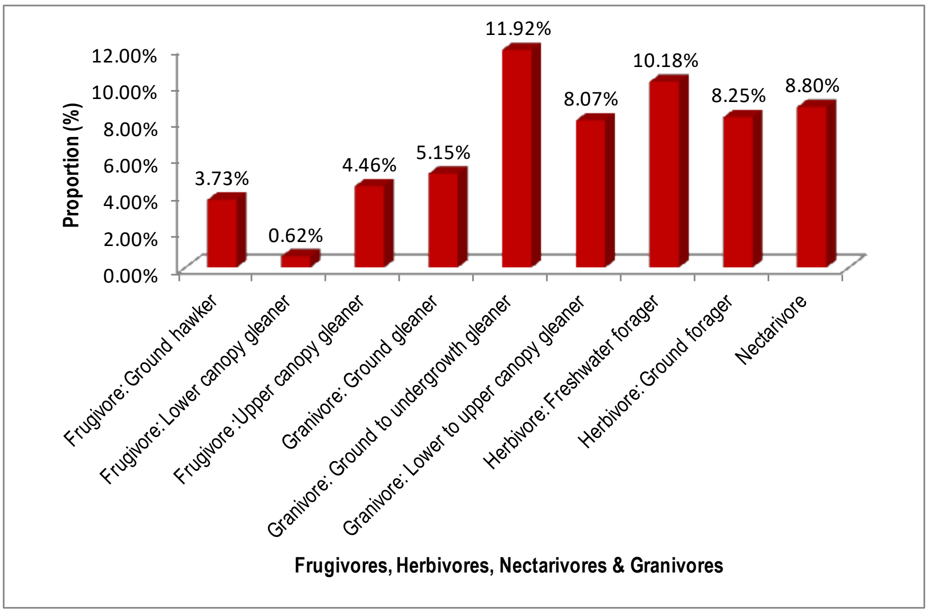


Figure 28: The proportion (%) of the bird species composition utilised by frugivore, herbivore, nectarivore and granivore bird species on the survey area.

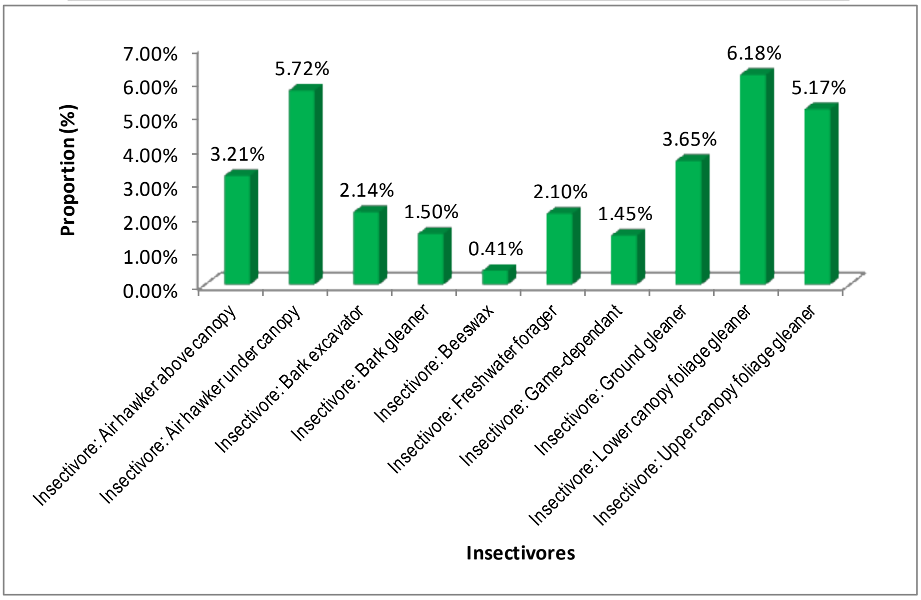


Figure 29: The proportion (%) of the bird species composition utilised by insectivorous bird species on the survey area.

5.6. Bird assemblage structure and composition: Altered point count data

Point count data was grouped according to major broad-scale habitat types and analysed to obtain a description of the dominant and discriminant ("indicator") bird compositions on each habitat. It provides important information on the bird compositions and functional guilds to be used, for example during monitoring programmes (e.g. rehabilitation monitoring).

5.6.1. Description of the bird species composition on each broad-scale habitat

5.6.1.1. Afromontane Rainforest (AfR)

The composition is characterised by high numbers of Eastern Double-collated Sunbird (*Cinnyris mediocris*), Cinnamon Bracken Warbler (*Bradypterus cinnamomeus*), Kikuyu White-eye (*Zosterops kikuyuensis*), Tropical Boubou (*Laniarius major*), Chestnut-throated Apalis (*Apalis porphyrolaema*), Grey Apalis (*Apalis cinerea*) and Placid Greenbul (*Phyllastrephus placidus*).

Indicator (discriminant) species restricted to the Afromontane Rainforest, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Apalis jacksoni (Black-throated Apalis)	1.50	1.68	1.11	2.11	Insectivore
Oriolus percivali (Montane Oriole)	0.60	1.20	0.92	1.51	Frugivore
Campethera taeniolaema (Fine-banded Woodpecker)	0.30	0.47	0.48	0.59	Insectivore
Apaloderma vittatum (Bar-tailed Trogon)	0.20	0.42	0.48	0.53	Insectivore
Elminia albonotata (White-tailed Crested Flycatcher)	0.20	0.24	0.32	0.31	Insectivore
Chamaetylas poliocephala (Brown-chested Alethe	0.10	0.24	0.32	0.30	Insectivore
Geokichla gurneyi (Orange Ground-thrush)	0.10	0.22	0.32	0.28	Insectivore
Lophoceros alboterminatus (Crowned Hornbill)	0.10	0.21	0.32	0.26	Insectivore

5.6.1.2. Afromontane Undifferentiated Forest (AUF)

The composition is characterised by high numbers of Dark-capped Bulbul (*Pycnonotus tricolor*), Streaky Seedeater (*Crithagra striolata*), Tropical Boubou (*Laniarius major*), Baglafecht Weaver (*Ploceus baglafecht*), Yellow-crowned Canary (*Serinus flavivertex*), Abyssinian Thrush (*Turdus abyssinicus*), Hunter's Cisticola (*Cisticola hunteri*), Bronzy Sunbird (*Nectarinia kilimensis*) and Golden-winged Sunbird (*Drepanorhynchus reichenowi*).

Indicator (discriminant) species restricted to the Afromontane Undifferentiated Forest, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Northern Double-collared Sunbird (*Cinnyris reichenowi*)	0.70	0.67	0.63	0.96	Nectarivore
Black-billed Weaver (*Ploceus melanogaster*)	0.45	0.40	0.44	0.51	Insectivore
Singing Cisticola (*Cisticola cantans*)	0.30	0.34	0.33	0.43	Insectivore
Green-headed Sunbird (*Cyanomitra verticalis*)	0.17	0.32	0.40	0.40	Nectarivore
Tambourine Dove (*Turtur tympanistria*)	0.28	0.35	0.43	0.44	Granivore
Mountain Wagtail (*Motacilla clara*)	0.13	0.29	0.36	0.36	Insectivore
Abyssinian Ground-thrush (*Geokichla piaggiae*)	0.11	0.19	0.29	0.24	Insectivore
Common Chiffchaff (*Phylloscopus collybita*)	0.06	0.06	0.21	0.08	Insectivore

5.6.1.3. Halophytic Vegetation (HalV)

The composition is characterised by high numbers of Dark-capped Bulbul (*Pycnonotus tricolor*), Grey-backed Camaroptera (*Camaroptera brevicaudata*), Rattling Cisticola (*Cisticola cheniana*), Willow Warbler (*Phylloscopus trochilus*), Red-capped Lark (*Calandrella cinerea*), Egyptian Goose (*Alopochen aegyptiaca*) and Common Waxbill (*Estrilda astrild*). The latter are confined to the woodland edge and open dry (not inundated) grassland along the edges of the Rift Valley lakes.

Indicator (discriminant) species restricted to the Halophytic Vegetation, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Egyptian Goose (*Alopochen aegyptiaca*)	2.30	1.34	0.61	1.44	Herbivore
Red-capped Lark (*Calandrella cinerea*)	1.00	1.23	0.60	1.33	Granivore
Western Yellow Wagtail (*Motacilla flava*)	0.60	1.09	0.75	1.17	Insectivore
Anteater Chat (*Myrmecocichla aethiops*)	0.40	0.79	0.48	0.86	Insectivore
Kittlitz's Plover (*Charadrius pecuarius*)	0.50	0.74	0.48	0.80	Insectivore
Plain-backed Pipit (*Anthus leucophrys*)	0.40	0.70	0.48	0.76	Insectivore
Common Rock Thrush (*Monticola saxatilis*)	0.20	0.63	0.48	0.68	Insectivore
Common Sandpiper (*Actitis hypoleucos*)	0.20	0.39	0.49	0.43	Insectivore
Rüppell's Starling (*Lamprotornis purpuroptera*)	0.30	0.29	0.33	0.31	Insectivore
Northern Wheatear (*Oenanthe oenanthe*)	0.10	0.28	0.33	0.30	Insectivore

5.6.1.4. Afromontane Bamboo (AfmB)

The composition is characterised by high numbers of Cinnamon Bracken Warbler (*Bradypterus cinnamomeus*), Eastern Double-collared Sunbird (*Cinnyris mediocris*), African Dusky Flycatcher (*Muscicapa adusta*), Baglafecht Weaver (*Ploceus baglafecht*), Yellow-crowned Canary (*Serinus flavivertex*), Abyssinian Thrush (*Turdus abyssinicus*), Kikuyu White-eye (*Zosterops kikuyuensis*), Brown Woodland Warbler (*Phylloscopus umbrovirens*) and White-eyed Slaty Flycatcher (*Melaenornis fischeri*).

Indicator (discriminant) species restricted to the Afromontane Bamboo, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Hartlaub's Turaco (*Tauraco hartlaubi*)	0.38	0.64	0.55	0.87	Frugivore
Waller's Starling (*Onychognathus walleri*)	1.00	0.36	0.37	0.49	Frugivore
Sharpe's Starling (*Poeoptera sharpii*)	0.13	0.22	0.34	0.29	Frugivore
Yellow-rumped Tinkerbird (*Pogoniulus bilineatus*)	0.13	0.21	0.37	0.35	Frugivore
Montane Yellow Warbler (*Iduna similis*)	0.38	0.66	0.56	0.72	Insectivore
Grey Cuckooshrike (*Ceblepyris caesius*)	0.63	0.60	0.56	0.65	Insectivore
Evergreen Forest Warbler (*Bradypterus lopezi*)	0.25	0.26	0.37	0.28	Insectivore
Rüppell's Robin-chat (*Cossypha semirufa*)	0.13	0.22	0.37	0.24	Insectivore

5.6.1.5. Riparian Wooded Vegetation (RWV)

The composition is characterised by high numbers of Superb Starling (*Lamprotornis superbus*), Rattling Cisticola (*Cisticola cheniana*), Ring-necked Dove (*Streptopelia capicola*), Yellow-breasted Apalis (*Apalis flavida*), Dark-capped Bulbul (*Pycnonotus tricolor*), Kenya Sparrow (*Passer rufocinctus*), Fischer's Lovebird (*Agapornis fischeri*) and Lesser Masked Weaver (*Ploceus intermedius*).

Indicator (discriminant) species restricted to the Riparian Wooded Vegetation, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Lesser Masked Weaver (*Ploceus intermedius*)	2.92	0.74	0.44	0.91	Granivore
Wattled Starling (*Creatophora cinerea*)	1.42	0.49	0.29	0.61	Frugivore
Arrow-marked Babbler (*Turdoides jardineii*)	0.33	0.47	0.43	0.58	Insectivore
Spurwinged Goose (*Plectropterus gambensis*)	3.08	0.44	0.43	0.55	Herbivore
Giant Kingfisher (*Megaceryle maxima*)	0.17	0.13	0.30	0.16	Carnivore
Black Cuckoo (*Cuculus clamosus*)	0.25	0.35	0.40	0.43	Insectivore
Common Scimitarbill (*Rhinopomastus cyanomelas*)	0.33	0.32	0.43	0.40	Insectivore
African Grey Hornbill (*Lophoceros nasutus*)	0.08	0.17	0.30	0.21	Frugivore

5.6.1.6. Upper Acacia Wooded Grassland (UAWG)

The composition is characterised by high numbers of Tawny-flanked Prinia (*Prinia subflava*), Rattling Cisticola (*Cisticola cheniana*), Ring-necked Dove (*Streptopelia capicola*), Red-cheeked Cordon-bleu (*Uraeginthus *bengalus*), Dark-capped Bulbul (*Pycnonotus tricolor*), Variable Sunbird (*Uraeginthus bengalus*), Streaky Seedeater (*Crithagra striolata*), Bronze Manikin (*Spermestes cucullata*) and Yellow Bishop (*Euplectes capensis*).

Indicator (discriminant) species restricted to the Upper *Acacia* Wooded Grassland, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Red-billed Firefinch (*Lagonosticta senegala*)	0.89	0.75	0.50	0.95	Granivore
Zitting Cisticola (*Cisticola juncidis*)	0.33	0.64	0.38	0.81	Insectivore
Brown Parisoma (*Curruca lugens*)	0.22	0.45	0.40	0.57	Insectivore
Red-faced Cisticola (*Cisticola erythrops*)	0.11	0.28	0.34	0.36	Insectivore
Quailfinch (*Ortygospiza atricollis*)	0.11	0.43	0.38	0.55	Granivore

5.6.1.7. Evergreen and Semi-evergreen Bushland and Thicket (ESEBT)

The composition is characterised by high numbers of Grey-backed Camaroptera (*Camaroptera brevicaudata*), Rattling Cisticola (*Cisticola cheniana*), Rufous-naped Lark (*Mirafra africana*), Red-cheeked Cordon-bleu (*Uraeginthus bengalus*), Dark-capped Bulbul (*Pycnonotus tricolor*), Variable Sunbird (*Uraeginthus bengalus*), Scarlet-chested Sunbird (*Chalcomitra senegalensis*), African Pipit (*Anthus cinnamomeus*) and Purple Granadier (*Granatina ianthinogaster*).

Indicator (discriminant) species restricted to the Evergreen and Semi-evergreen Bushland and Thicket, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Rufous-naped Lark (*Mirafra africana*)	0.56	1.05	0.64	1.33	Granivore
African Pipit (*Anthus cinnamomeus*)	0.98	1.04	0.54	1.31	Insectivore
Purple Grenadier (*Granatina ianthinogaster*)	0.76	0.84	0.62	1.05	Granivore
African Grey Flycatcher (*Melaenornis microrhynchus*)	0.52	0.57	0.48	0.72	Insectivore
Golden-breasted Bunting (*Emberiza flaviventris*)	0.41	0.55	0.45	0.70	Granivore
Red-faced Crombec (*Sylvietta whytii*)	0.30	0.45	0.49	0.57	Insectivore
Red-fronted Barbet (*Tricholaema diademata*)	0.20	0.33	0.41	0.42	Frugivore
White-bellied Canary (*Crithagra dorsostriata*)	0.17	0.30	0.31	0.38	Granivore
White-browed Scrub-robin (*Cercotrichas leucophrys*)	0.09	0.27	0.31	0.34	Insectivore

5.6.1.8. Edaphic Wooded Grassland (EWG)

The composition is characterised by high numbers of Baglafecht Weaver (*Ploceus baglafecht*), Northern Fiscal (*Lanius humeralis*), Hadeda Ibis (*Bostrychia hagedash*), Levaillant's Cisticola (*Cisticola tinniens*), Streaky Seedeater (*Crithagra striolata*), Lesser Swamp Warbler (*Acrocephalus gracilirostris*), Black Crake (*Zapornia flavirostra*), Western Cattle Egret (*Bubulcus ibis*), Red-billed Quelea (*Quelea quelea*) and Pin-tailed Whydah (*Vidua macroura*).

Indicator (discriminant) species restricted to the Edaphic Wooded Grassland, but less abundant or absent in the other habitat types include:

Species	Mean abundance (number of individuals per habitat type)	Mean dissimilarity	Consistency	% contribution	Primary Trophic Guild
Levaillant's Cisticola (*Cisticola tinniens*)	1.09	1.34	0.67	1.49	Insectivore
African Snipe (*Gallinago nigripennis*)	0.45	0.73	0.44	0.81	Insectivore
Highland Rush Warbler (*Bradypterus centralis*)	0.27	0.48	0.45	0.53	Insectivore
Jackson's Widowbird (*Euplectes jacksoni*)	0.73	0.48	0.30	0.53	Granivore
Winding Cisticola (*Cisticola marginatus*)	0.09	0.30	0.30	0.33	Insectivore
Southern Red Bishop (*Euplectes orix*)	0.25	0.25	0.30	0.27	Granivore
Striped Crake (*Aenigmatolimnas marginalis*)	0.18	0.21	0.31	0.24	Insectivore
African Rail (*Rallus caerulescens*)	0.09	0.18	0.31	0.20	Insectivore

5.6.2. Diversity and Species Richness

The highest number of species (species richness) was observed from the Afromontane Undifferentiated Forest with 189 species recorded, followed by the Evergreen and semi-evergreen bushland and thicket habitat where 185 species were recorded. Low richness values were observed from the Edaphic wooded grasslands and Afromontane Bamboo habitat with respectively 48 and 49 species recorded (Table 11). The highest number of individuals was observed from the Riparian wooded vegetation while the lowest number of individuals was observed from the Edaphic wooded grassland (Table 11).

Table 11: A summary of the observed species richness and number of individuals confined to the broad-scale habitat types on the survey area.

Broad-scale Habitat	Number of Species (S)	Mean number of individuals per habitat (N)	Shannon-Wiener (H'(log$_e$))
Afromontane Rainforest (AfR)	60	38.50	3.77
Afromontane Undifferentiated forest (AUF)	189	67.06	4.19
Afromontane Bamboo (AfmB)	49	46.25	3.50
Halophytic Vegetation (HalV0	90	40.20	3.97
Upper *Acacia* Wooded Grassland (UAWG)	66	37.44	3.81
Riparian Wooded Vegetation (RWV)	137	82.92	4.15
Evergreen and Semi-evergreen Bushland and Thicket (ESEBT)	185	36.22	4.59
Edaphic Wooded Grassland (EWG)	48	27.36	3.39

Rarefaction curves aim to describe bird diversity on the survey area by taking into account both species richness and evenness. It is also provides a better descriptor of diversity since it is not sensitive to sample size. Rarefaction predicts the expected number of species at a particular sample size based on randomization algorithms (also less constrained by statistical assumptions). Rarefaction indicated that the bird species diversity on forest habitat types (AUF, AfR and AfmB) and upper *Acacia* wooded grassland types are very similar to each other and appears to be stable, while a high diversity (and evenness) is expected from the riparian wooded vegetation (Figure 30). In addition, habitat units where disturbances were prevalent (e.g. grazing and clearing) tend to have lower diversities such as the Evergreen and semi-evergreen bushland and thicket and edaphic wooded grasslands (Figure 30).

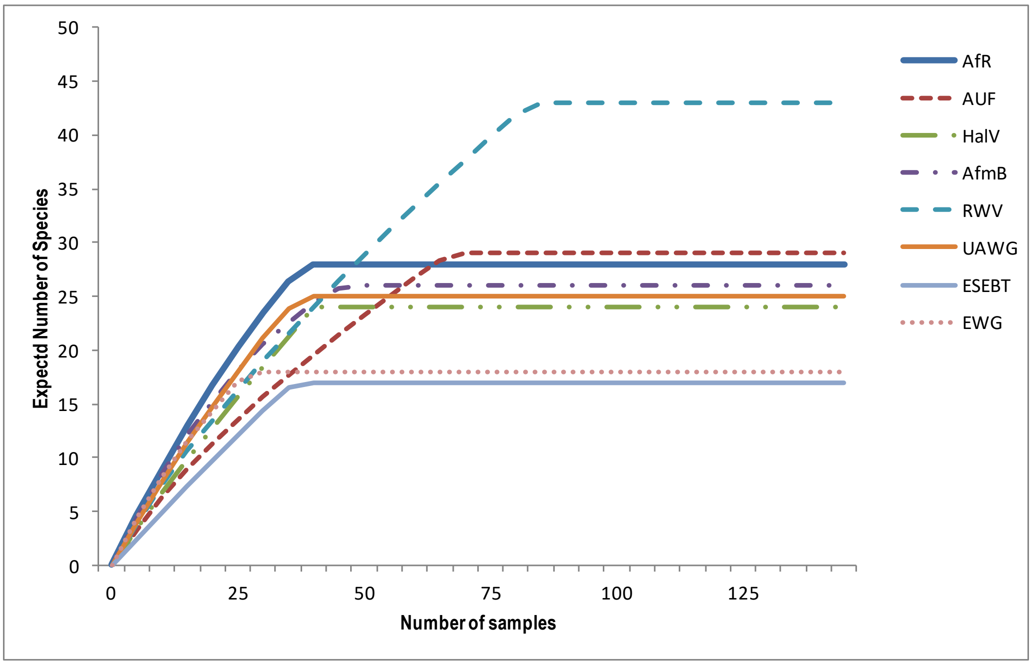
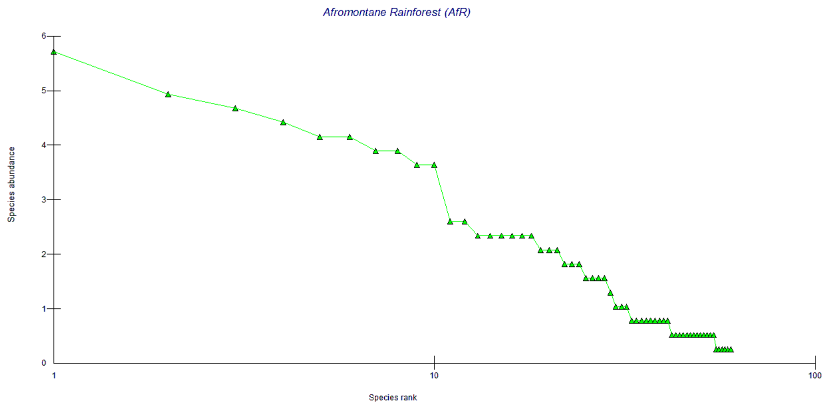


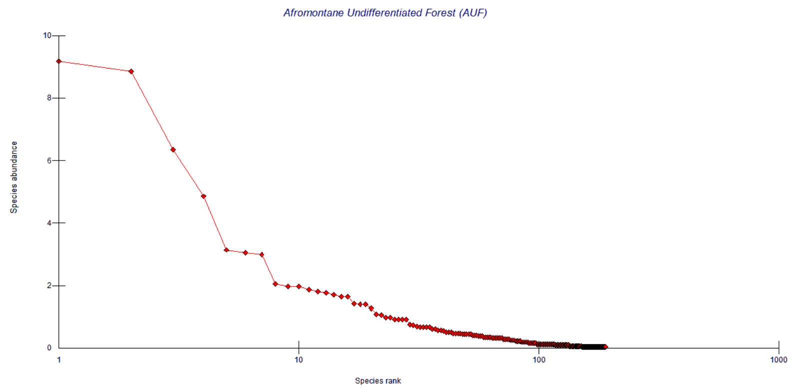
Figure 30: Rarefaction curves for the bird assemblages on eight broad-scale habitat types on the survey area.

5.6.3. Patterns of succession and Equitability

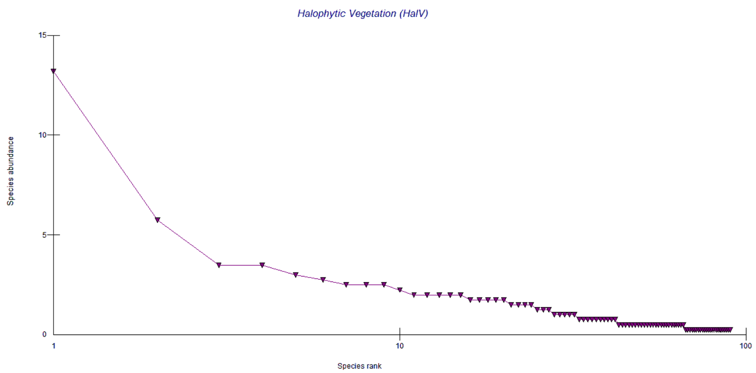
Species abundance curves (Figure 31) describe the ranking or "packing" of species in each habitat type. It also describes the equitability of individuals relative to their species. It provides an overview of the successional stage of a particular habitat. Therefore, late successional habitat types are theoretically stable and show a high number of species "packing" at higher ranks. In addition, late successional habitat types will have most of their species distributed at low abundances and the curves will have shallow slopes. Early successional or recently disturbed habitat types will host fewer species at higher ranks (low abundances) and will show curves with elevated (steep) slopes. Fewer species were observed "packing" at high ranks in the Afromontane Undifferentiated Forest (AUF) habitat. The latter habitat does hold a high number of bird species, including forest-dependant species, although large sections were also transformed and consisted of secondary fragments which provide habitat for forest edge and generalist species, and hence explain s the steep slope of the curve. The woodland (c. ESEBT and RWV), edaphic wooded grassland and Halophytic vegetation show more species "packing" at intermediate ranks, thereby implying that these habitat types contain secondary species, as well as species with generalised habitat requirements although also containing many "late-successional species" at intermediate levels of disturbance. The remaining forest habitat (AfR and AfmB) and Upper *Acacia* Wooded Grassland (UAWG) have shallower slopes, thereby suggesting that these areas retained most of there specialist species and hold fewer secondary species (Figure 32).


Afromontane Rainforest (AfR)
Species abundance
Species rank
0
1
2
3
4
5
6
1
10
100

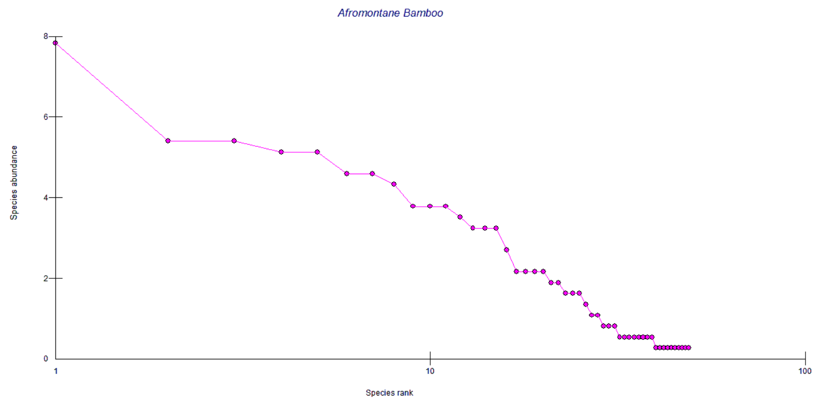
a)


Afromontane Undifferentiated Forest (AUF)
Species abundance
Species rank
0
2
4
6
8
10
1
10
100
1000

b)


Halophytic Vegetation (HalV)
Species abundance
Species rank
0
5
10
15
1
10
100

c)


Afromontane Bamboo
Species abundance
Species rank
0
2
4
6
8
1
10
100

d)

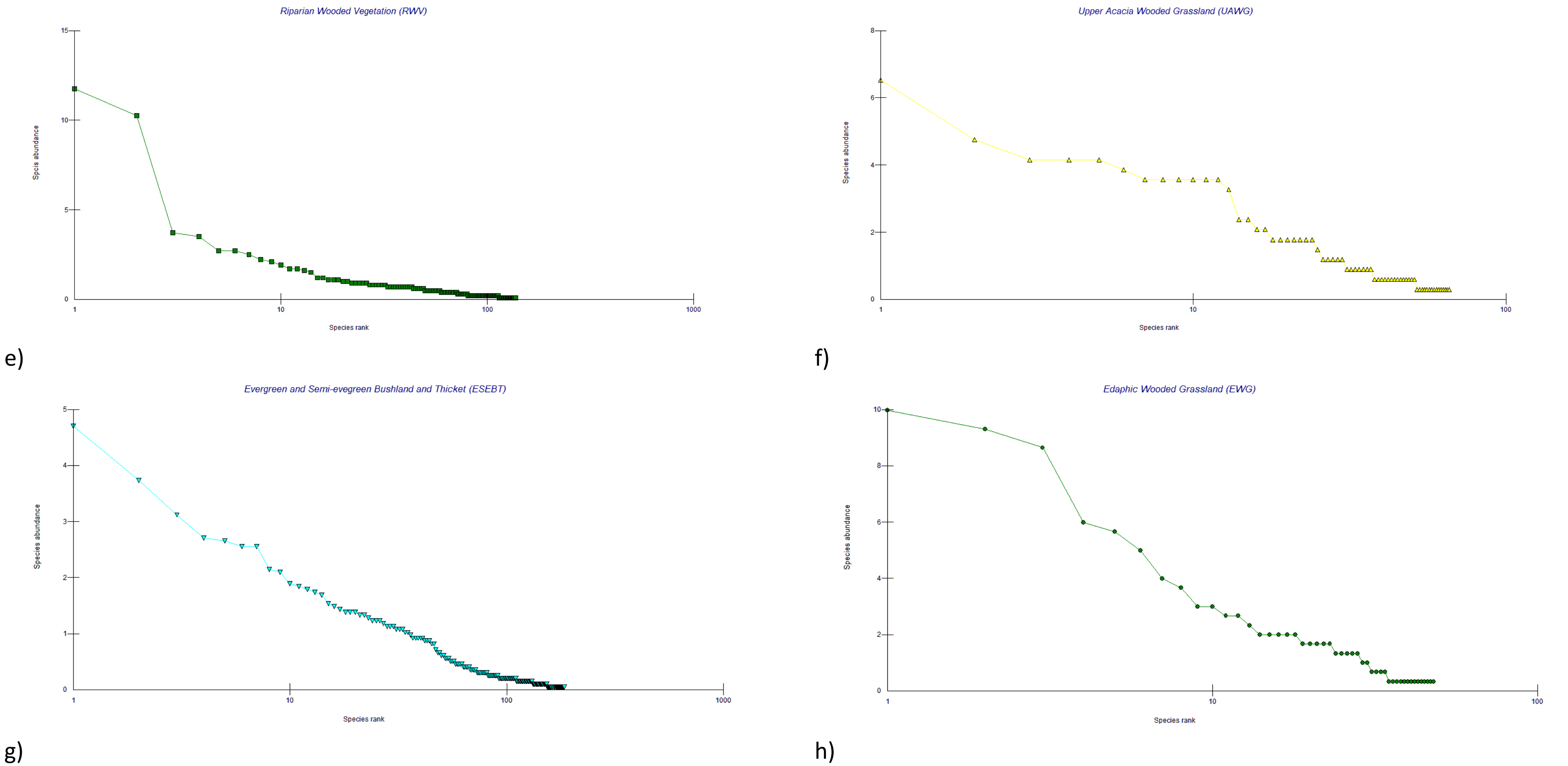


Figure 31: Species abundance curves for bird assemblages collected by means of point counts in eight broad-scale habitat types: (a) Afromontane Rainforest (AfR), (b) Afromontane Undifferentiated Forest (UAF), (c) Halophytic Vegetation (HalV), (d) Afromontane Bamboo (AfmB), (e) Riparian Wooded Vegetation (RWV), (f) Upper *Acacia* Wooded Grassland (UAWG), (g) Evergreen and semi-evergreen Bushland and Thicket (ESEBT) and (h) Edaphic Wooded Grassland (EWG). The vertical axis (y) represents relative abundance and the horizontal axis (x) species rank.

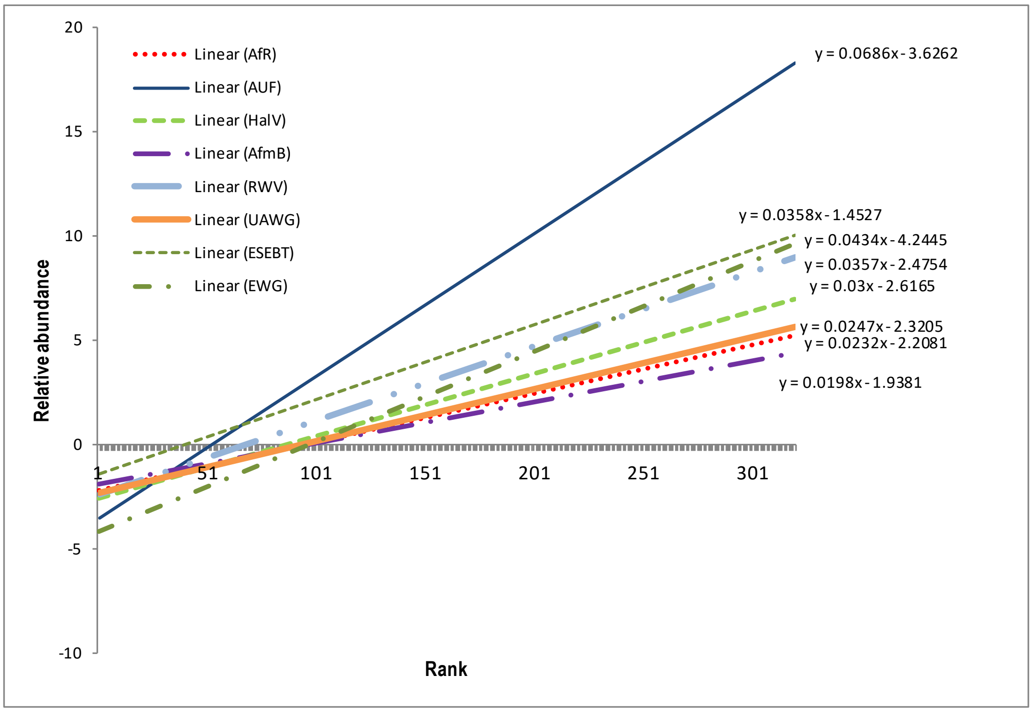


Figure 32: Calculated slopes obtained from species abundance curves for bird assemblages collected by means of point counts in eight broad-scale habitat types. Slopes are derived from trendline equations and are represented by m where y=mx+c.

5.6.4. Guild Structure

5.6.4.1. Vertical Partitioning

Vertical guild partitioning at each of the habitat types shows that a large proportion of species confined to the aquatic habitat types (such as RWV and EWG) are terrestrial foragers, while the highest proportion of lower canopy foragers occurs in forest habitat types (AfR and AUF). The upper canopy species are well represented in all of the habitat types, while middle canopy foragers were more prominent in the Afromontane Bamboo forest types and in evergreen and semi-evergreen bushland and thicket habitat (Figure 33).

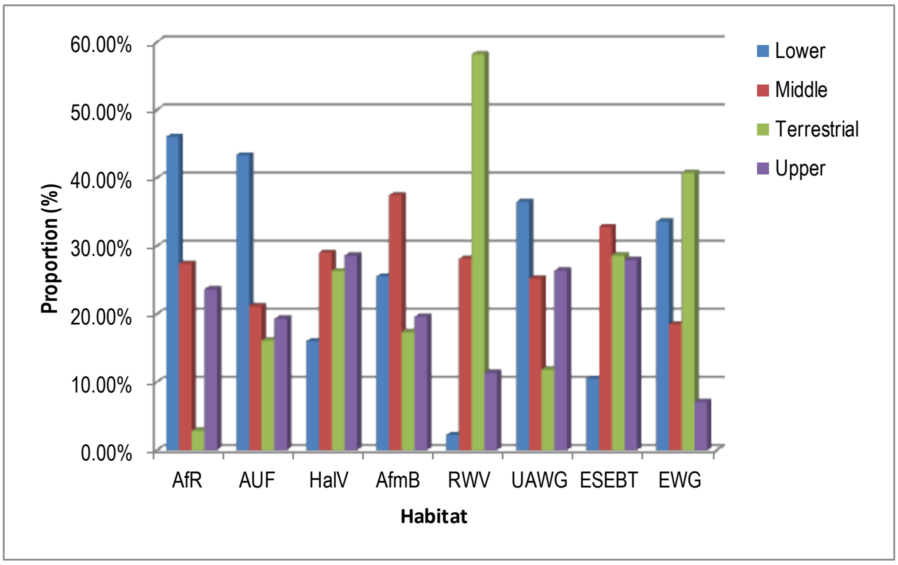


Figure 33: The proportion (%) of vertical partitioning among bird species in the different habitat types along the survey area.

5.6.4.2. Primary Tropic Guilds

An analysis of trophic guilds for the bird species of the respective habitat types shows a high proportion of omnivores (mainly crows) and herbivores (mainly ducks and geese) occur respectively in Afromontane Bamboo and Edaphic Wooded Grassland and in Afromontane Undifferentiated Forst and Riparian Wooded Vegetation. Nectarivores (sunbirds) are present in virtually all the habitat types but reach high numbers in Afromontane Rainforest and Upper *Acacia* Wooded Grassland. Granivores were conspicuous in open habitat represented by wooded grassland habitat (e.g. UAWG and EWG). Frugivores and insectivores were abundant in Afromontane Rainforest although occurring in low numbers in Edaphic Grassland habitat, where carnivores (mainly piscivorous water-and wading birds) are a common feature (Figure 34 and Table 12).

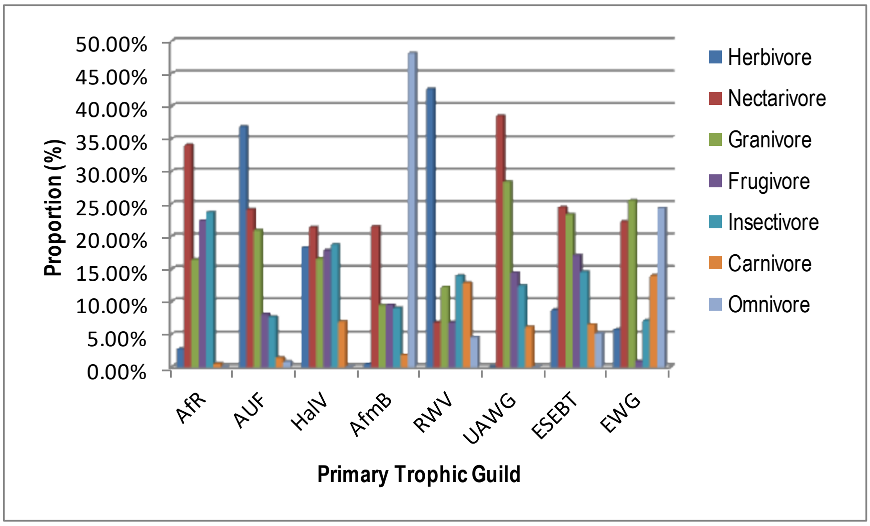


Figure 34: The proportion (%) of primary tropic guilds for bird species in the different habitat types.

Table 12: A summary of the proportion (%) of primary guilds for bird species in each habitat on the survey area. High values are indicated in red and low values in blue.

Primary Guild	AfR	AUF	HalV	AfmB	RWV	UAWG	ESEBT	EWG
Herbivore	2.77%	36.86%	18.30%	0.45%	42.67%	0.00%	8.72%	5.73%
Nectarivore	34.05%	24.18%	21.41%	21.55%	6.80%	38.54%	24.51%	22.33%
Granivore	16.49%	20.97%	16.63%	9.47%	12.26%	28.43%	23.39%	25.56%
Frugivore	22.45%	8.11%	17.87%	9.51%	6.80%	14.45%	17.17%	0.87%
Insectivore	23.76%	7.69%	18.82%	9.02%	14.01%	12.45%	14.59%	7.12%
Carnivore	0.48%	1.41%	6.97%	1.84%	12.92%	6.13%	6.51%	14.03%
Omnivore	0.00%	0.79%	0.00%	48.16%	4.53%	0.00%	5.11%	24.36%

5.6.4.3. Foraging Strategy (Secondary guilds)

A high membership of guilds (according to the number of foraging strategies) was observed in the Afromontane Undifferentiated Forest (AUF) and Evergreen and semi-evergreen Bushland and thicket habitat with 21 foraging guilds, followed by the Riparian Wooded Vegetation habitat with a membership of 20 guilds. The lowest membership occurred in the Upper *Acacia* Wooded Grassland habitat (Table 13).

The largest proportion of carnivore guild membership was observed in the Evergreen and semi-evergreen Bushland and thicket habitat, which provides habitat for many large iconic, and often threatened birds of prey. Freshwater foragers such as herons, waders, shorebirds and storks were best represented in Riparian Wooded Vegetation as well as moist and inundated grassland bordered by Edaphic Wooded Grassland (Table 13).

A high diversity of frugivore bird species was present in forest habitat (mainly AUF and AfR), while granivore birds species were equally distributed among the various habitat types, although high numbers of ground to undergrowth gleaners occurred in Afromontane Undifferentiated Forest (mainly waxbills and crimsonwings). The forest habitat types provide refuge for a high diversity of doves, pigeons, waxbills, barbets and hornbills, as well as greenbuls and turacos. Frugivore ground gleaners were uncommon and represented by small-bodied *Columba* doves which are primarily restricted to the forest floor. Granivore ground gleaners are represented by a diversity of *Streptopelia* doves, Ploceid weavers and larks attained high numbers in modified bushland habitat (ESEBT). Small-bodied granivores (both ground to lower undergrowth gleaners and lower to upper canopy gleaners) are represented by a diversity of estrildid taxa (waxbills and firefinches), viduids (whydahs), and fringillids (canaries), all attaining high numbers in open, recently modified habitat dominated by grasses and plantations in wooded grassland and forest habitat (Table 13).

The highest guild diversity found in insectivorous species occurs in Riparian Wooded Vegetation, followed by Afromontane Undifferentiated Forest and Evergreen and semi-evergreen Bushland and thicket habitat. Air hawkers such as bee-eaters were prominent over Halophytic Vegetation (lakes), while below-canopy hawkers such as flycatchers (Muscicapidae) were prominent in late succesional forest, such as Rainforest. Bark excavators such as woodpeckers were more abundant in tall Riparian Wooded Vegetation, while bark gleaners (e.g. wood hoopoes and scimitarbills) were more abundant in tall *Acacia* woodland along Halophytic Vegetation (lakes). Honeyguides, which feed almost exclusively on beeswax, were prominent in evergreen bushland, and freshwater foragers (e.g. shorebirds and waders) were exclusive to wetlands where Riparian Wooded Vegetation and Epahic Wooded Grassland dominate. Ground gleaners (e.g. ambush predators) and oxpeckers attained higher number in Riparian woodland. Foliage gleaners, which probably represent the highest biomass of all insectivorous species, were best represented in habitat with tall canopy constituents and high vertical heterogeneity such as Afromontane Rainforest and Upper *Acacia* Wooded Grassland. High number of omnivores (mainly crows) occurred in secondary and edge habitat of Afromontane Bamboo (Table 13).

Table 13: A summary of the proportion (%) of secondary guilds utilised by bird species on each habitat on the survey area.

Secondary Guild	AfR	AUF	HalV	AfmB	RWV	UAWG	ESEBT	EWG
Carnivore: Air hawker	0.00%	0.00%	0.00%	0.00%	1.42%	0.00%	0.98%	0.00%
Carnivore: Arboreal hawker	0.00%	1.45%	0.00%	0.00%	0.00%	0.00%	0.98%	0.00%
Carnivore: Freshwater forager	0.00%	0.52%	1.82%	2.64%	3.54%	1.54%	0.08%	2.48%
Carnivore: Ground hawker	0.24%	0.58%	2.75%	0.00%	4.69%	3.56%	4.17%	10.34%
No. of Carnivore Guilds	**1**	**3**	**2**	**1**	**3**	**2**	**4**	**2**
Frugivore: Ground hawker	9.20%	4.83%	0.00%	11.88%	0.00%	0.00%	2.94%	0.00%
Frugivore: Lower canopy gleaner	9.20%	0.48%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Frugivore: Upper canopy gleaner	6.25%	3.46%	6.45%	5.07%	2.38%	6.88%	7.24%	0.48%
No. of Frugivore Guilds	**3**	**3**	**1**	**2**	**1**	**1**	**2**	**1**
Granivore: Ground gleaner	0.00%	2.07%	5.45%	0.00%	4.25%	7.68%	13.09%	10.17%
Granivore: Ground to undergrowth gleaner	6.90%	21.72%	6.90%	3.30%	0.24%	16.38%	2.45%	19.85%
Granivore: Lower to upper canopy gleaner	8.46%	8.36%	4.54%	10.45%	5.15%	14.25%	8.11%	11.19%
No. of Granivore Guilds	**2**	**3**	**3**	**2**	**3**	**3**	**3**	**3**
Herbivore: Freshwater forager	0.00%	22.42%	0.00%	0.36%	2.44%	0.00%	0.18%	4.33%
Herbivore: Ground forager	2.30%	1.29%	16.72%	0.00%	33.26%	0.00%	9.14%	0.00%
No. of Herbivore Guilds	**1**	**2**	**1**	**1**	**2**	**0**	**2**	**1**
Insectivore: Air hawker above canopy	3.45%	3.74%	8.72%	0.00%	0.35%	6.14%	3.67%	0.00%
Insectivore: Air hawker under canopy	11.29%	3.90%	10.70%	10.80%	3.60%	5.03%	8.28%	0.54%
Insectivore: Bark excavator	2.30%	1.05%	4.36%	0.66%	4.72%	0.00%	3.10%	0.00%
Insectivore: Bark gleaner	0.00%	0.48%	3.27%	0.00%	4.60%	0.00%	2.20%	0.00%
Insectivore: Beeswax	0.00%	0.10%	0.00%	0.00%	0.28%	0.00%	1.57%	0.00%
Insectivore: Freshwater forager	0.00%	2.26%	4.09%	0.00%	4.33%	0.38%	0.00%	8.19%
Insectivore: Game-dependant	0.00%	0.00%	0.00%	0.00%	7.08%	0.00%	1.96%	0.00%
Insectivore: Ground gleaner	0.14%	0.89%	4.22%	0.49%	9.60%	3.07%	6.55%	4.09%
Insectivore: Lower canopy foliage gleaner	20.98%	6.24%	5.72%	11.63%	1.24%	11.52%	5.02%	1.49%
Insectivore: Upper canopy foliage gleaner	9.33%	4.04%	7.37%	6.41%	3.29%	7.18%	6.96%	4.03%
No. of Insectivore Guilds	**6**	**9**	**8**	**5**	**10**	**6**	**9**	**5**
Omnivore: Ground forager	0.00%	0.32%	0.00%	25.08%	1.42%	0.00%	1.96%	11.91%
No. of Omnivore Guilds	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**1**
Total Number of Guilds	**13**	**21**	**15**	**12**	**20**	**12**	**21**	**13**

6. DISCUSSION

6.1. Spatial sampling overview

The sampling sufficiency reached approximately 11 % of the total grid cells sampled by means of point counts and approximately 26 % of the total grid cells within the Local Assessment Area were traversed on foot or by vehicle. Although the total number of grids that were sampled appeared to be low, it should be noted that priority was given to natural habitat while aiming to visit at least each of the broad-scale habitat types and special habitat zones on the Local Assessment Area. However, the total sampling sufficiency was considered as appropriate even though only 11% of the Local Assessment Area was sampled, which detected 73% of the predicted avifaunal richness on the study site (which is >50%).

6.2. Species accumulation curves and sampling efficiency

The species accumulation curve (see Figure 4) for the bird point count dataset showed that sampling sufficiency had been reached after approximately 80 sites. If the Michaelis-Menten curve is applied to predict the total number of species, then 85 % of the predicted species were captured. However, additional sampling at 120 sites captured 90 % of the predicted species and this was regarded as sufficient. If 90% of the predicted number of species captured is regarded as a satisfactory level of sampling (in accordance with Moreno & Halffter, 2000), then sampling was adequate across all point counts (in total). Experience from sampling where a single "homogenous" habitat is involved has shown that the accumulation of species is rapid, and for a "homogenous" woodland habitat approximately 40 samples is required to detect 85% of the species, which is already 50% of the required samples required when compared to the current project. Therefore, survey areas which comprehend a large variety of habitat, especially when extremes in floristic structure are evident (e.g. forest vs. grassland) will often require additional sampling effort in order to detect not only a large array of different species, but also different "species compositions" are involved. Such sampling effort becomes more intense when each of the prevalent habitat units also represents a disturbance gradient ranging from late-successional habitat to pioneer or recently perturbed habitat.

For this reason, a large number of samples were required during both seasons to reach 90 % of the predicted species, which is an indication of the high spatial heterogeneity topography and habitat diversity along the highway alignment. However, sampling sufficiency during the dry and wet seasons captured respectively 83.4 and 88 % of the number of species predicted by the Michaelis-Menten model, and we are confident that 90 % of the species were sampled during both surveys even though the Michaelis-Menten model suggested that additional sampling was required.

6.3. Taxonomic Diversity and Ornithological Observations

The overall species richness on the survey area was high with 439 bird species recorded, which 38 % of the entire avifaunal richness in Kenya (according Lepage, 2021). This is not surprising since the available habitat types on the survey area ranges from forest to open woodland and grassland habitat along with a number of wetland features. Therefore, at least 25 % of the species richness includes forest-dependant bird species, while another 25 % comprises of waterbirds and aquatic-associated species.

Approximately 162 species are also expected to occur (apart from the observed 439 species) but were absent or not detected during the survey sessions. Nevertheless, many of these species were not detected since they are ether naturally rare or occur in very low abundances in the survey area, while some were absent since they are only present during passage (some of the Palearctic *Acrocephalus* and *Luscinia* species) or are nocturnal. Based on the field guide by Stevenson and Fanshawe (2020), at least seven of the observed species during the study were "out of range species" or new records. The distribution ranges of these species are marginal to the survey area, and are uncommon to rare in the Kenyan highlands, while being widespread in the lowland areas east of the Rift Valley (and hence east of the project area).

Some of the observed species also include races or subspecies that are of geographic interests. For example, the *chyulensis* subspeces of the Long-billed Pipit (*Anthus similis*) was observed in the Kenya Wildlife Service's sanctuary, and may represent a new record west of Nairobi. This race, which if locally known as the "Nairobi" Pipit was once thought to be an undescribed species due to its habits of walking along branches when flushed into a tree (an atypical behaviour of Long-billed Pipit). In addition, the *senex* race of the White-headed Barbet (*Lybius leucocephalus*) is endemic to the Kenyan highlands. It will be a Kenyan endemic when recognised by the International Ornithological Congress (IOC) as a full species. However, it is already elevated to full species by the BirdLife International/ Handbook of Birds of the World (BLI/HBW)[10] classification, where it is known as the "Brown-and-white Barbet". Similarly, the *keniensis* subspecies which was formerly part of the Black-crowned Waxbill (*Estrilda nonnula*) was recently elevated to a full species known as Kandt's Waxbill (*E. kandti*) which is represented by a isolated populations confined to the Kenyan and Ugandan highlands. One of the species expected to occur, namely the Moorland Francolin (*Scleroptila psilolaema*) is also represented by a isolated populations in Kenya and Uganda, which it is already elevated to a full species known as the Elgon Francolin (*S. elgonensis*) by the BirdLife International/ Handbook of Birds of the World (BLI/HBW) classification.

6.4. Notes on the Expected species list, vetting process and excluded species

Approximately 27 % of the bird species expected to occur on the survey area was not observed during the two survey campaigns. These include 161 species of which their potential occurrence were carefully vetted according data provided by Lewis and Pomeroy (1989), Stevenson and Fanshawe (2020), Zimmerman et al. (2005) and more importantly, by the Kenya Bird Atlas Project. Reasons for the inclusion and exclusion of species are as follow:

- ***Resident species***: A number of species were ominously absent from the survey area during the surveys, but were included since they are widespread in the area (according to the Kenya Bird Map Project). It is unknown why these species were not detected during surveys, although possible reasons may be a function of elevated levels of anthropogenic activities along the highway alignment and the degraded nature of some of the habitat types on the Local Assessment Area (within the 2 km buffer area). Typical examples include Grey-capped Social Weaver (*Pseudonigrita arnaudi*), Northern White-crowned Shrike (*Eurocephalus ruppelli*), Red-throated Tit (*Melaniparus fringillinus*), Rufous-breasted Sparrowhawk (*Accipiter rufiventris*) and Marico Sunbird (*Cinnyris mariquensis*). These species were included to the expected species list.
- ***Excluded species***: Some species have distribution ranges that are peripheral to the survey area but are uncommon in the Rift Valley or in the Kenyan highlands (many of these are uncommon west of Nairobi). Typical examples include Banded Parisoma (*Curruca boehmi*), Northern Pied Babbler (T*urdoides hypoleuca*), Spotted Palm Thrush (*Cichladusa guttata*) and Black-cheeked Waxbill *(Brunhilda charmosyna*). These species were excluded from the expected species list.
- ***Palearctic migratory passerine taxa***: Careful vetting of the genera *Luscinia* (nightingales), *Ficedula* (pied flycatchers) and locustellinid (river, bracken and rush warblers), acrocephalinid (reed and "typical" warblers) and phylloscopinid (leaf-warblers) warblers were required. Some of these species occur during passage and then present for a brief period of time on the survey area (few days). These species may be overlooked if the timing of surveys doesn't correspond with their time of passage. However, some species were eliminated from the expected species list as these appear on average to be uncommon on the survey area (according to multiple sources of information), while the majority of these appear to be common north and east of the Kenyan highlands. Typical species included are the Basra Reed Warbler

[10] An alternative avian classification supported by BirdLife International and the Handbook of Birds of the World, which is also more frequently used by the IUCN. However, the classification in this document follows that of the IOC world bird list. The IOC compliments other primary world bird lists (e.g. BLI/HBW list, Clements checklist and the Howard & Moore checklist) which differ from each other in primary goals and taxonomic philosophies.

(*Acrocephalus griseldis*), Great Reed Warbler (*A. arundinaceus*), Eastern Olivaceus Warbler (*Iduna pallida*), Icterine Warbler (*Hippolais icterina*), Wood Warbler (*Phylloscopus sibilatrix*), River Warbler (*Locustella fluviatilis*), Thrush Nightingale (*Luscinia luscinia*), Common Nightingale (*L. megarhynchos*) and White-throated Robin (*Irania gutturalis*).

- ***Red-fronted Parrot (Poicephalus gulielmi)***: The Red-fronted Parrot was excluded from the expected species list even though it is known from the nearby Kikuyu Escarpment Forest block (e.g. Kinale Forest). It is of the opinion that the forest patches located within the Local Assessment Area (within the 2 km buffer area) is sub-optimal for this species to occur. It is regarded as an irregular visitor to these forest fragments, although it appears to be widespread in suitable habitat west of the highway alignment.
- ***Common Ostrich (Struthio camelus)***: The occurrence of natural populations of free-ranging ostriches is a subject of debate. We are of the opinion that the ostrich population on the survey area are either introduced or no longer regarded as free-ranging individuals (including those observed within conservancies). The Common Ostrich was excluded from the observed and expected species list.
- ***Extreme vagrants***: A number of species are vagrant to the survey area and were only recorded once or twice within the area over a period of 10-20 years. These species, such as the Saker Falcon (*Falco cherrug*) were omitted from the expected species list.
- ***Specialist taxa***: Some species is restricted to specialist habitat which were absent from the survey area. A typical example includes the Taita Falcon (*Falco fasciinucha*) which breeds at prominent inselbergs and cliff faces. Species that are dependent on specialised habitat and where such habitat is absent were excluded from the expected species list.
- ***Sharpe's Longclaw (Macronyx sharpei)***: Sharpe's Longclaw is endemic to Kenya and also globally endangered (IUCN, 2021). The largest sub-population of this species in Kenya was formerly confined to the Kinangop grasslands (IUCN, 2021), which is also located in close proximity to the survey area. It was recently observed (c. 21 April 2021) from two pentad grids that are sympatric to the survey area (according to the Kenya Bird Map), although it is of the opinion that these birds were observed on higher lying grassland patches that are located outside of the survey area. The possibility exists that these observations were erroneous and may have been confused with the sympatric Yellow-throated Longclaw (*M. croceus*). These pentad grids also overlap with the Thika-Mango Flyover grasslands. This species was searched for at several grassland patches within the Local Assessment Area, including the Thika-Mango Flyover grasslands and was not found. Given the degraded condition (shortly grazed grassland) of these grassland patches, especially owing to persistent disturbances and trampling caused by cattle and human activities (sometimes several hundred individuals of sheep and cattle was observed on small patches of grassland), the probability that this species occurs on the physical impact zone of the project area (e.g. approximately 100 m on either side of the road reserve) is low. However, due to the proximal distribution range of Sharpe's Longclaw populations to survey area, including the two recent observations from the Kenya Bird Map project, a precautionary approach was adopted and this species was retained as an expected species.

6.5. Species of conservation concern and endemism

Fifty-two (52) of the observed bird species are restricted to a particular biome, of which 85 % of bird species restricted specifically to the Afrotropical Highlands biome were present on the survey area. A high diversity of species restricted to the Afrotropical Highlands biome was located within the varius forest habitat, most notably the Afromontane Rainforest and Afromontane Bamboo forest. Approximately 13% of the biome-restricted species is also confined to the Somali-Masai biome which occurred predominantly in woodland habitat, especially the ESEBT habitat.

Ten species endemic to East Africa were observed on the survey area, including three species endemic to the Serengeti Plains and Kenyan Highlands Endemic Bird Area. Only one species (c. Kikuyu White-eye *Zosterops kikuyuensis*) observed on the study site is entirely endemic to Kenya. The prevalence of the majority of observed endemic species was higher in forest habitat.

The observed species are summarised as follow (all of these are endemic to East Africa):

- ***Species endemic to the Serengeti Plains Endemic Bird Area***. The Grey-crested Helmetshrike (*Prionops poliolophus*) is the only species preset on the survey area. It is uncommon on the survey area where it was observed during two independent observations: (1) from tall *Acacia xanthophloea* woodland at Soysambu Conservancy along the edge of Lake Elmenteita. It was observed mixing with race *cristatus* of the White-crested Helmetshrike (*P. plumatus*). The (2) second observation consists of a small flock flying across the highway approximately 3 km north of the entrance gate to the Kigio Conservancy.
- ***Species endemic to the Kenyan Highlands Bird Area***. Observed species included the widespread and common Hunter's Cisticola (*Cisticola hunteri*) as well as Jackson's Widowbird (*Euplectes jacksonii*). The latter was recorded at a single locality corresponding to an upland wetland surrounded by grazed grassland (EWG).
- ***Species endemic to Kenya***. The Kikuyu White-eye (*Zosterops kikuyuensis*) was the only "true" Kenyan endemic species observed on the survey area. It was commonly observed in mixed bird parties in forest and upland woodland habitat.
- ***Species endemic to East Africa***. Ten East African endemic species have been observed on the study survey area. Those with a frequency of occurrence include the Kikuyu White-eye (*Zosterops kikuyuensis*), Hunter's Cisticola (*Cisticola hunteri*), Kenya Sparrow (*Passer rufocinctus*) and Eastern Double-collared Sunbird (*Cinnyris mediocris*). Two of the species are often commensal with human-induced habitat and include the Kenya Sparrow (*Passer rufocinctus*) and the Swahili Sparrow (*P. suahelicus*).

Nineteen (19) threatened and near threatened species (IUCN, 2021) occurred on the survey area, consisting of (Figure 20 - Figure 24):

- two critically endangered species (c. Rüppell's Vulture *Gyps rueppelli* and African White-backed Vulture *Gyps africanus*);
- five endangered species (c. Steppe Eagle *Aquila nipalensis*, Martial Eagle *Polemaetus bellicosus*, Bateleur *Terathopius ecaudatus*, Grey Crowned Crane *Balearica regulorum,* Secretarybird *Sagittarius serpentarius*);
- three vulnerable species (c. Tawny Eagle *Aquila rapax*, Southern Ground Hornbill *Bucorvus leadbeateri* and Sooty Falcon *Falco concolor*); and
- nine near threatened (c. Crowned Eagle *Stephanoaetus coronatus*, Pallid Harrier *Circus macrourus,* Lesser Flamingo *Phoeniconaias minor*, Curlew Sandpiper *Calidris ferruginea*, Chestnut-banded Plover *Charadrius pallidus*, Mountain Buzzard *Buteo oreophilus*, Grey-crested Helmetshrike *Prionops poliolophus*, Jackson's Widowbird *Euplectes jacksoni* and Kori Bustard *Ardeotis kori*).

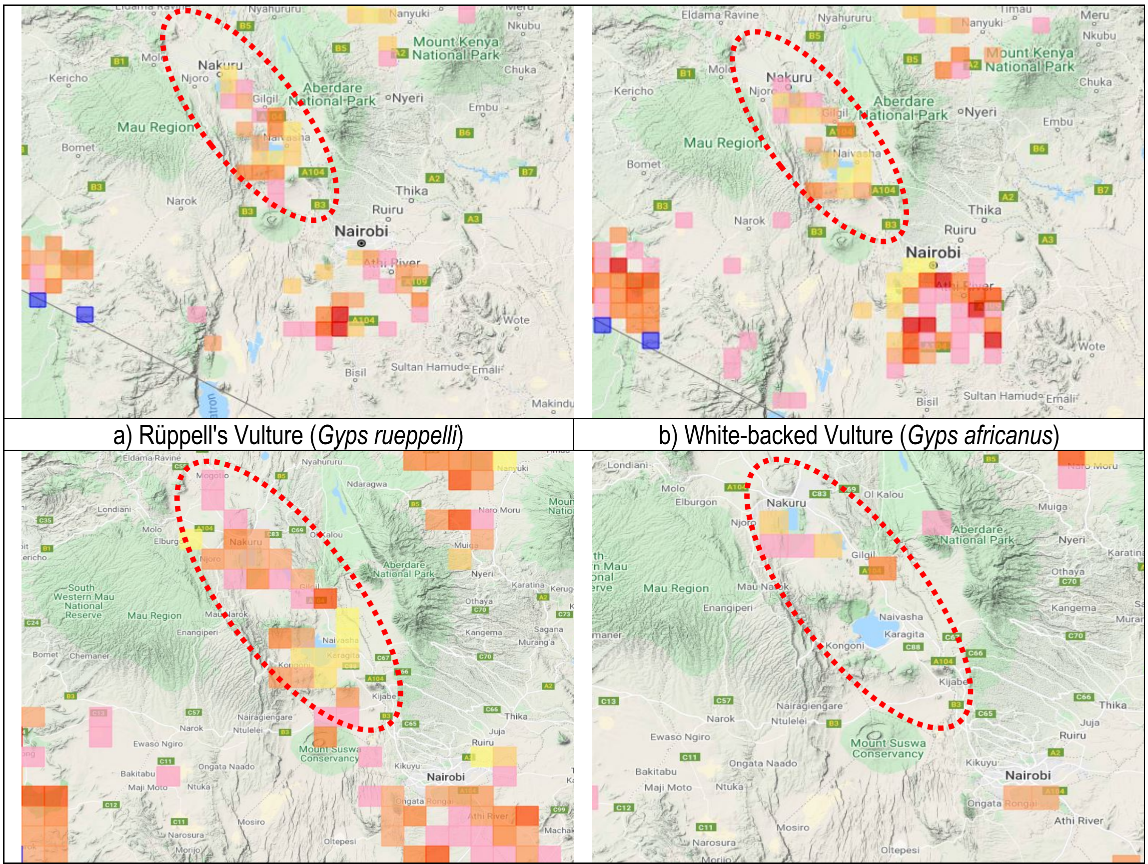
Many of these consist of large-bodied birds which are either scavengers or large terrestrial species which require large home range sizes or are "k-selected" species, meaning that they have long incubation, gestation and immature stages before the offspring reach sexual maturity (meaning that they are long-lived but take a number of years to reach adulthood). It was evident that a large number of threatened and near threatened bird species occur on the survey area.

6.5.1.1. Scavenging Birds of Prey

Four of the observed bird species are primarily scavenging species. Two of these are critically endangered *Gyps* vultures (Rüppell's Vulture *G. rueppelli* and White-backed Vulture G*. africa*nus), one is a vulnerable *Aquila* eagle (Tawny Eagle *A. rapax*) and the last species represented by the endangered Bateleur (*Terathopius ecaudatus*). The conservation status of these four species was recently uplisted due to ongoing declines of more than 90% in these populations over the past three generations (>50 years) due to habitat loss (mainly where pastoral land is converted in to agriculture), poisoning, direct persecution (mainly for medicinal and cultural reasons) as well as mortalities due to collisions with electrical infrastructure (BirdLife International, 2017a; 2018a, 2018b & 2020a). In East Africa, poisoning through the use of the toxic pesticide carbofuran and the use diclofenac, a non-steroidal anti-inflammatory drug often used for livestock, are some of the primary reasons for the decline observed in these species, especially for the two *Gyps* vulture species. The two *Gyps* vulture species also declines by 69% in central Kenya between 2001 and 2003 (Ogada and Keesing, 2010).

These species, with the exception of the Bateleur are relatively widespread in the survey area (according to the Kenya Bird Map) where most of these species are located in protected areas such as Lake Nakuru National Park and the conservancies. The occurrence of Bateleur on the study region is scattered, with most of the records from Nakuru National Park and the eastern parts of Lake Elmenteita (according to the Kenya Bird Map). It appears that the survey area holds important sub-populations of these species in the country, which is directly attributed to the presence of game species (other important sub-populations occur in the Nairobi National Park and the Masai Mara area). During the 2021 surveys, all four species were confined to ESEBT and/ or RWV habitat (Figure 20, Figure 35 and Figure 36):

- **Rüppell's Vulture (*G. rueppelli*) -** Several observations of soaring individuals, mainly over Soysambu conservancy and Marula Estates. A group of approximately 20 - 50 individuals were also observed feeding on a giraffe carcass at Soysambu in the company of White-backed Vultures (*G. africanus*) (outside of the Local Assessment Area).
- **White-backed Vulture (*G. africanus*)** - Approximately 5-10 individuals observed feeding on a giraffe carcass at Soysambu in the company of Rüppell's Vultures (*G. rueppelli*) (outside the Local Assessment Area).
- **Tawny Eagle (*A. rapax*) -** Three independent records of individuals and pairs observed at Marula Estates and open ESEBT habitat along the A8 South Highway. A pair was also observed mating on a powerline pylon on Marula Estates.
- **Bateleur (*T. ecaudatus*) -** A single observation of two birds over Marula Estates.



a) Rüppell's Vulture (*Gyps rueppelli*) | b) White-backed Vulture (*Gyps africanus*)

c) Tawny Eagle (*Aquila rapax*) | d) Bateleur (*Terathopius ecaudatus*)

Figure 35: The distribution range of threatened scavenging birds of prey (genera *Gyps, Aquila* and *Terathopius*) relative the survey area according to the Kenya Bird Map. The stippled oval shows the approximate position of the Regional Assessment Area.

a) | b)

Figure 36: An example of (a) feeding Rüppell's Vultures (*Gyps rueppelli*) at Soysambu conservancy and a (b) roosting Tawny Eagle (*Aquila rapax*) on a pylon at Marula Estates.

6.5.1.2. Large Terrestrial Bird species

Four of the observed bird species are large bodied terrestrial species which occur mainly on open savannoid grassland and upland wooded grassland. Two of these are endangered species (Secretarybird *Sagittarius serpentarius* and Grey Crowned Crane *Balearica regulorum*), one is a vulnerable species (Southern Ground-hornbill *Bucorvus leadbeateri*) and the last species represented by the near threatened Kori Bustard (*Ardeotis kori*). According to extant records (according to the Kenya Bird Map) is evident that the Grey Crowned Crane is widespread on the survey area with several observations from both upland marsh/wetland habitat and lowland open savannoid grassland, including cultivated land. The Secretarybird is also widespread, although most of the observations stem from protected areas south of Naivasha and between Lakes Nakuru and Elmenteita. The Kori Bustard appears to be localised, with most of all recent observations south of Lake Naivasha, while observations of the Southern Ground-hornbill is scant and scattered (Figure 37). It appears that the presence of herbivore game species and well-managed livestock ranches are critically important for the persistence of these bird species on the survey area.

During the 2021 surveys, all four species were confined to open ESEBT habitat and upland EWG habitat (Figure 22, Figure 37 and Figure 38):

- **Grey Crowned Crane (*B. regulorum*)** - The conservation status of Grey Crowned Crane was uplisted to Endangered since its global population has declined by more than 50% in the last 19 years due to habitat loss and the illegal trade of wild birds and eggs (BirdLife International, 2016a). It is predicted that the global population will decrease by 80% after a period of three generations (>40years).

  Several individuals, which include pairs, including large flocks of over 80 individuals were observed from several EWG habitat (mainly associated with upland ponds and wetland features) and on open savannoid grassland and cultivated land on Marula Estates. It is possible that observations of paired birds at EWG habitat, including Manguo Pond suggest that these birds breed on the survey area.

- **Secretarybird (*S. serpentarius*)** - This species has experienced severe declines in the last few years, including in Kenya owing to habitat fragmentation and habitat loss (BirdLife International, 2020b). This species requires large home range sizes, and it is not uncommon for them to travel on average between 20 to 30 km per day (Whitecross et al., 2019).

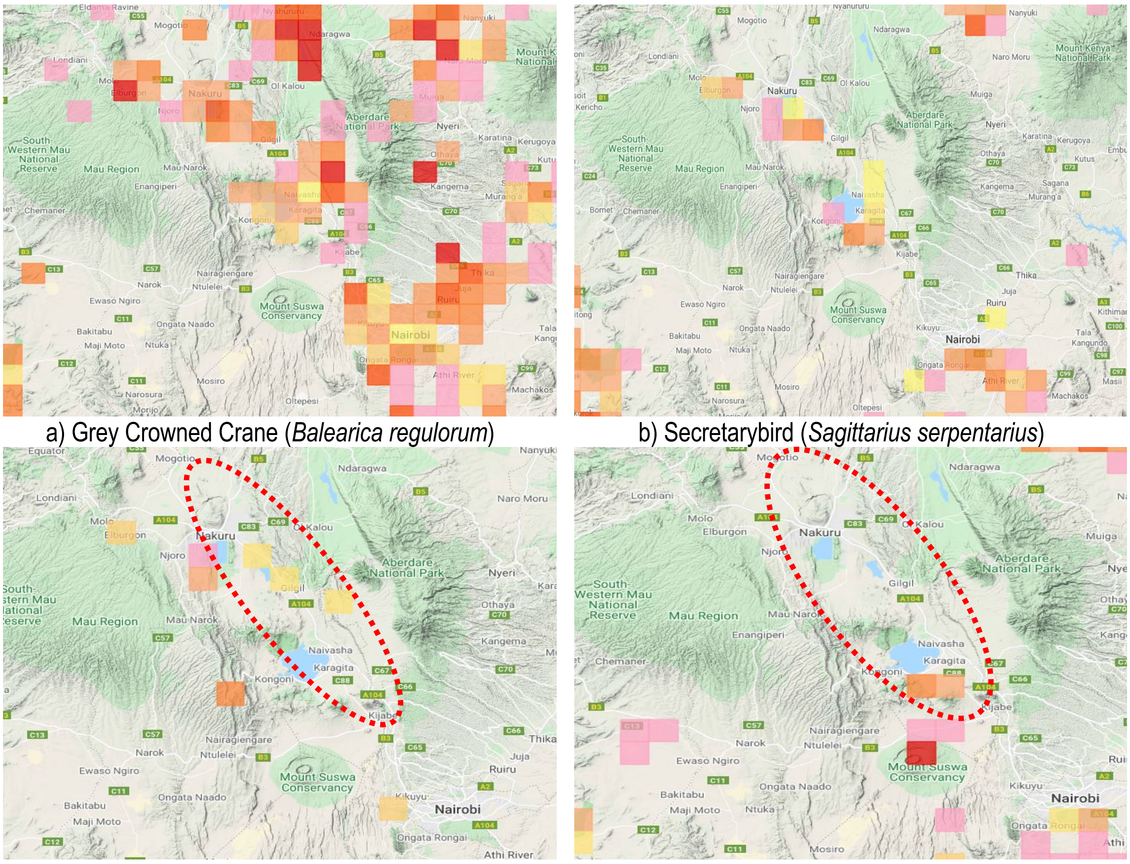
  Up to seven independent observations were made during the survey period, which include either single or pairs of foraging individuals. Important foraging habitat is represented by open ESEBT habitat on Soysambu and Marula Estates, as well as the open savannoid habitat west of the A8 South Highway.

- **Southern Ground-hornbill (*B. leadbeateri*)** - This species is vulnerable and has experienced population declines owing to the loss of breeding habitat (mainly to make way for small scale agricultural plots) and through persecution (BirdLife International, 2016b). In Kenya, it is predicted that only 10% of suitable habitat remains due to widespread livestock grazing resulting in erosion of suitable habitat (BirdLife International, 2016b).

  It was uncommon on the survey area, with one to two groups (consisting of 3 - 4 individuals) resident in Soysambu and Marula Estates. It was not observed outside of protected areas.

- **Kori Bustard (*A. kori*)** - This species is suspected to be undergoing a moderate population decrease due to habitat degradation and collisions with powerlines, of which the extent of occurrence of its habitat in East Africa has contracted by 21% (Senyatso et al.,2012; BirdLife International, 2016c).

  It was uncommon on the survey area and only observed from open savannoid grassland located west of the A8 South Highway based on two observations representing three individuals in total.



a) Grey Crowned Crane (*Balearica regulorum*) b) Secretarybird (*Sagittarius serpentarius*)

c) Southern Ground-hornbill (*Bucorvus leadbeateri*) d) Kori Bustard (*Ardeotis kori*)

Figure 37: The distribution range of threatened and near threatened large terrestrial bird species (genera *Balearica, Sagittarius, Bucorvus* and *Ardeotis*) relative the survey area according to the Kenya Bird Map. The stippled oval shows the approximate position of the Regional Assessment Area.

Figure 38: An example of (a-b) Grey Crowned Crane (*Balearica regulorum*), (c-d) Secretarybird (*Sagittarius serpentarius*) and (e-f) Southern Ground-hornbill (*Bucorvus leadbeateri*) observed on the survey area.

6.5.1.3. Birds of Prey

Six of the observed bird species include birds of prey species (apart from those mentioned earlier). Two of these are endangered species (Martial Eagle *Polemaetus bellicosus* and Steppe Eagle *Aquila nipalensis*), one is a vulnerable species (Sooty Falcon *Falco concolor*) and the remaining species represented by the near threatened Mountain Buzzard (*Buteo oreophilus*), Crowned Eagle (*Stephanoaetus coronatus*) and Pallid Harrier (*Circus macrourus*). According to extant records (according to the Kenya Bird Map) is evident that the Martial Eagle and

Steppe Eagle are mainly confined to ESEBT habitat in protected areas (conservancies and Lake Nakuru National Park), while the Mountain Buzzard and Crowned Eagle occurs in forested habitat, with the highest reporting rates from Afromontane Rainforest (AfR) in the south of the survey area. The Sooty Falcon appears to be rare in the survey area with only a few records for the area from scattered localities. The Pallid Harrier appears to be more generalist in habitat preference, and was widely observed from open savannoid grassland (Figure 39). The Sooty Falcon, Pallid Harrier and Steppe Eagle are non-breeding Palearctic visitors to the area.

During the 2021 surveys, four of the species were confined to open ESEBT habitat, while two were confined to Afromontane forest and RWV habitat (Figure 21, Figure 39 and Figure 40):

- **Martial Eagle (*P. bellicosus*)** - In Kenya, 65% reduction in reporting rates was observed for Martial Eagles in unprotected areas, while an increase was observed of 113% from protected areas, thereby implying that the distribution of species in Kenya is nearly restricted to protected areas (BirdLife International, 2020c).

  It was uncommon to rare on the survey area, with a single bird observed from ESEBT habitat at Marula Estates. It is possible that fewer than three breeding pairs occur on the survey area.

- **Steppe Eagle (*A. nipalensis*)** - This species is a non-breeding visitor to the survey area, with most of the observations representing birds on passage through the Rift Valley. In Africa, its main threats include collisions associated with powerlines and wind energy projects, and to a lesser degree also indirect pesticide poisoning (BirdLife International, 2020d).

  It was uncommon on the survey area, with two observations representing a single bird observed at Marula Estates, and two individuals on passage along the A8 South Highway. All observations were made from ESEBT habitat.

- **Sooty Falcon (*F. concolor*)** - This species is represented by a very small and highly local population which breeds in the Middle East (including Libya and Egypt), with most of the population wintering in Madagascar (including a proportion that winters in coastal Mozambique and eastern South Africa). It was recently uplisted to the vulnerable category following the small and highly localised breeding population (Birdlife International, 2019). Reasons for its decline remains unclear since breeding colonies are invariably inaccessible, and it suggested that declining pressures occur on its wintering grounds and while it is on migration (Birdlife International, 2019).

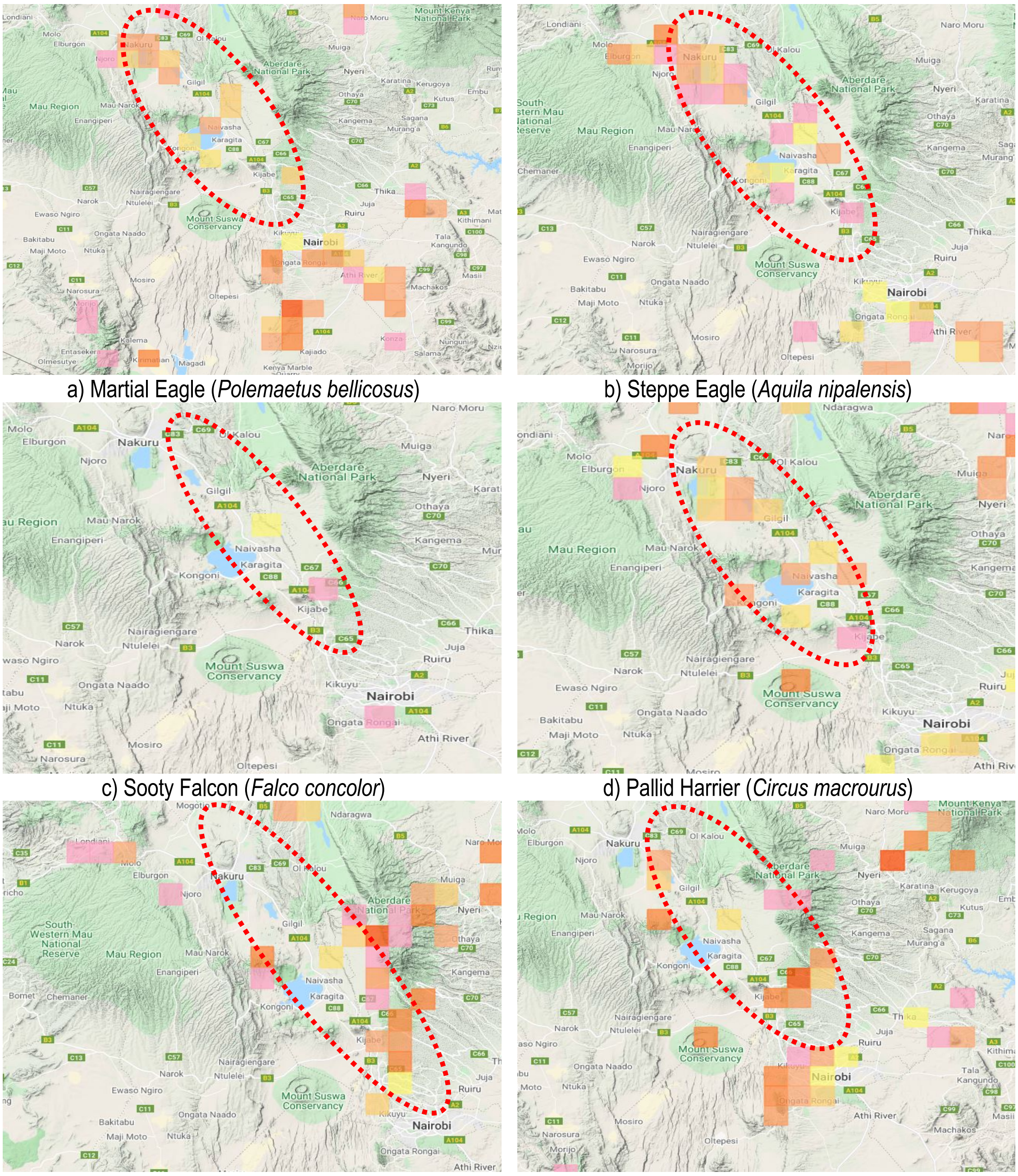
  It is probably an overlooked passage migrant on the survey area, which confirms the low reporting rates for this species in the region (according to the Kenya Bird Map). A single observation (representing two birds) was made during April 2021 from ESEBT habitat on Soysambu. These birds were probably on passage to their northern breeding grounds.

- **Pallid Harrier (*C. macrourus*)** - This species is fairly common on its wintering grounds of which two observations were made during February 2021 from open ESEBT habitat on the survey area. It is regarded as a regular non-breeding visitor to the survey area.

- **Mountain Buzzard (*B. oreophilus*)** - This species is near threatened since the population is suspected to be declining owing to its high affinity for Afromontane forest habitat (BirdLife International, 2016d). It was mainly observed in the southern section of the survey area, with up to five observations of birds (mainly pairs) from fairly intact (or large patches) Afromontane forest (AUF, AfR and AfmB). It is resident on the survey area, with the largest sub-population confined to the Kinale Forest block (AfR).

- **Crowned Eagle (*S. coronatus*)** - This species is still considered to be widespread, but listed as near threatened by deforestation, hunting (poaching) and electrocution on utility networks (BirdLife

International, 2018c). It is fairly common in suitable habitat on the survey area, where it was observed from three localities representing RWV and Afromontane habitat (AUF and AfR). An active nest is also present in tall riverine forest vegetation at Soysambu.



a) Martial Eagle (*Polemaetus bellicosus*)

b) Steppe Eagle (*Aquila nipalensis*)

c) Sooty Falcon (*Falco concolor*)

d) Pallid Harrier (*Circus macrourus*)

c) Mountain Buzzard (*Buteo oreophilus*)

d) Crowned Eagle (*Stephanoaetus coronatus*)

Figure 39: The distribution range of threatened and near threatened birds of prey relative the survey area according to the Kenya Bird Map. The stippled oval shows the approximate position of the Regional Assessment Area.


a)


b)

Figure 40: An example of (a) a Crowned Eagle (*Stephanoaetus coronatus*) and (b) an active nest observed at Soysambu conservancy (see arrow).

6.5.1.4. Near threatened Passerine Bird species

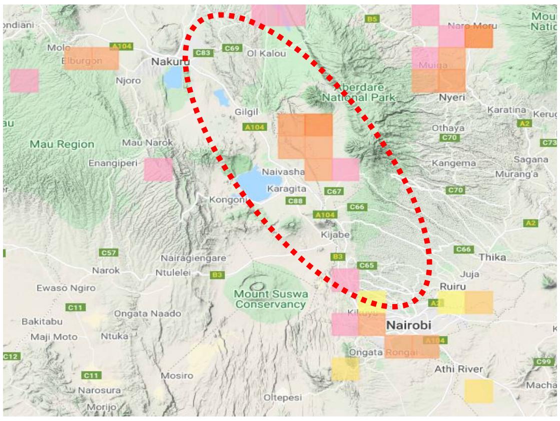
Two of the observed bird species include smaller near threatened passerine species. The Jackson's Widowbird (*Euplectes jacksoni*) is regarded as near threatened since its preferred habitat, namely open montane grassland vulnerable towards habitat fragmentation and destruction owing to intensified agricultural development and livestock production (BirdLife International, 2016e). In addition, fires is also used to control tick loads during the dry season, which often result in the temporary displacement of this species from suitable habitat (BirdLife International, 2016e). The Jackson's Widowbird is uncommon on the survey area recent records show that it occurs east of the survey area at the Kinangop Plateau (where it is uncommon according to Lens and Bennun, 1996) and near Mau Summit (Figure 41).

The Grey-crested Helmetshrike (*Prionops poliolophus*) was also with scattered observations from the eastern shores of Lake Elmenteita, Marula Estates and in Lake Nakuru National Park (Figure 41). The Grey-crested Helmetshrike is near threatened owing to its highly localised global distribution range and ongoing habitat transformation for agricultural production (BirdLife International, 2016f).

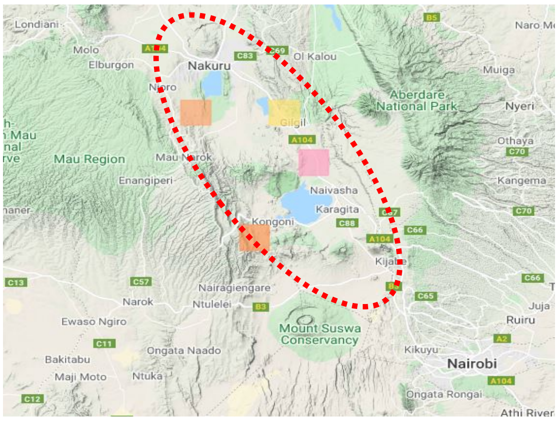
During the 2021 surveys, the Jackson's Widowbird and Grey-crested Helmetshrike were respectively confined to open EWG habitat and ESEBT habitat (Figure 23 and Figure 41):

- **Jackson's Widowbird (*E. jacksoni*) -** It was uncommon on the survey area, with a single observation representing eight birds (one male and seven females) from open dry grassland alongside a upland seep zone (EWG) near Mau Summit.

- **Grey-crested Helmetshrike (*P. poliolophus*) -** This species was uncommon to rare on the survey area with two independent observations from ESEBT habitat. One of these represent a small flock observed from Leleshwa woodland near the entrance to the Kigio wildlife sanctuary (February 2021), while the other observation (April 2021) was made from tall *Acacia xanthophloea* woodland along the western shoreline of Lake Elmenteita in the Soysambu conservancy. The latter represented individuals observed within a flock of White-crested Helmetshrikes (*P. plumatus*) (Figure 42).



a) Jackson's Widowbird (*Euplectes jacksoni*)



b) Grey-crested Helmetshrike (*Prionops poliolophus*)

Figure 41: The distribution range of near threatened passerine bird species relative the survey area according to the Kenya Bird Map. The stippled oval shows the approximate position of the Regional Assessment Area.


a)


b)


c)

Figure 42: An example of (a) a Grey-crested Helmetshrike (*Prionops poliolophus* - background) alongside a White-crested Helmetshrike (*P. plumatus*) at Soysambu conservancy, (b) a Grey-crested Helmetshrike (*P. poliolophus*) - note the white "wingbar"and the absence of a yellow eye wattle and (c) a White-crested Helmetshrike (*P. plumatus*) - note the absence of a white "wingbar" and the presence of a yellow eye wattle.

6.5.1.5. Waterbirds and Shorebirds

Three of the observed bird species include near threatened waterbird and shorebird species. Two of these (Lesser Flamingo *Phoeniconaias minor* and Curlew Sandpiper *Calidris ferruginea*) show high reporting rates at Lake Elmenteita and Lake Nakuru (Figure 43), with lower rates reported for Lake Naivasha (according to the Kenya Bird Map) and both were observed in high numbers on the survey area on halophytic vegetation (HalV) along Lake Elmenteita. The Chestnut-banded Plover (*Charadrius pallidus*) is currently only known from Lakes Turkana, Magadi and Natron in Kenya, while it occurs as vagrants/wanderers elsewhere. There are no recent records of Chestnut-banded Plover from the survey area (Figure 43), apart from a single individual that was observed during April 2021 at Lake Elmenteita.

The Black-tailed Godwit (*Limosa limosa*) and Eurasian Curlew (*Numenius arquata*) are two near threatened that could also occur along the shoreline of Lake Elmenteita during the austral summer, although none were observed during the February and April 2021 surveys (Figure 43). Both species are non-breeding Palearctic visitors, of which the Godwit is regarded as a regular foraging visitor, while the Curlew is an uncommon to irregular visitor to the survey area.

During the 2021 surveys, it was evident that these species are restricted to HalV habitat at Lake Elmenteita (Figure 24, Figure 43 and Figure 44):

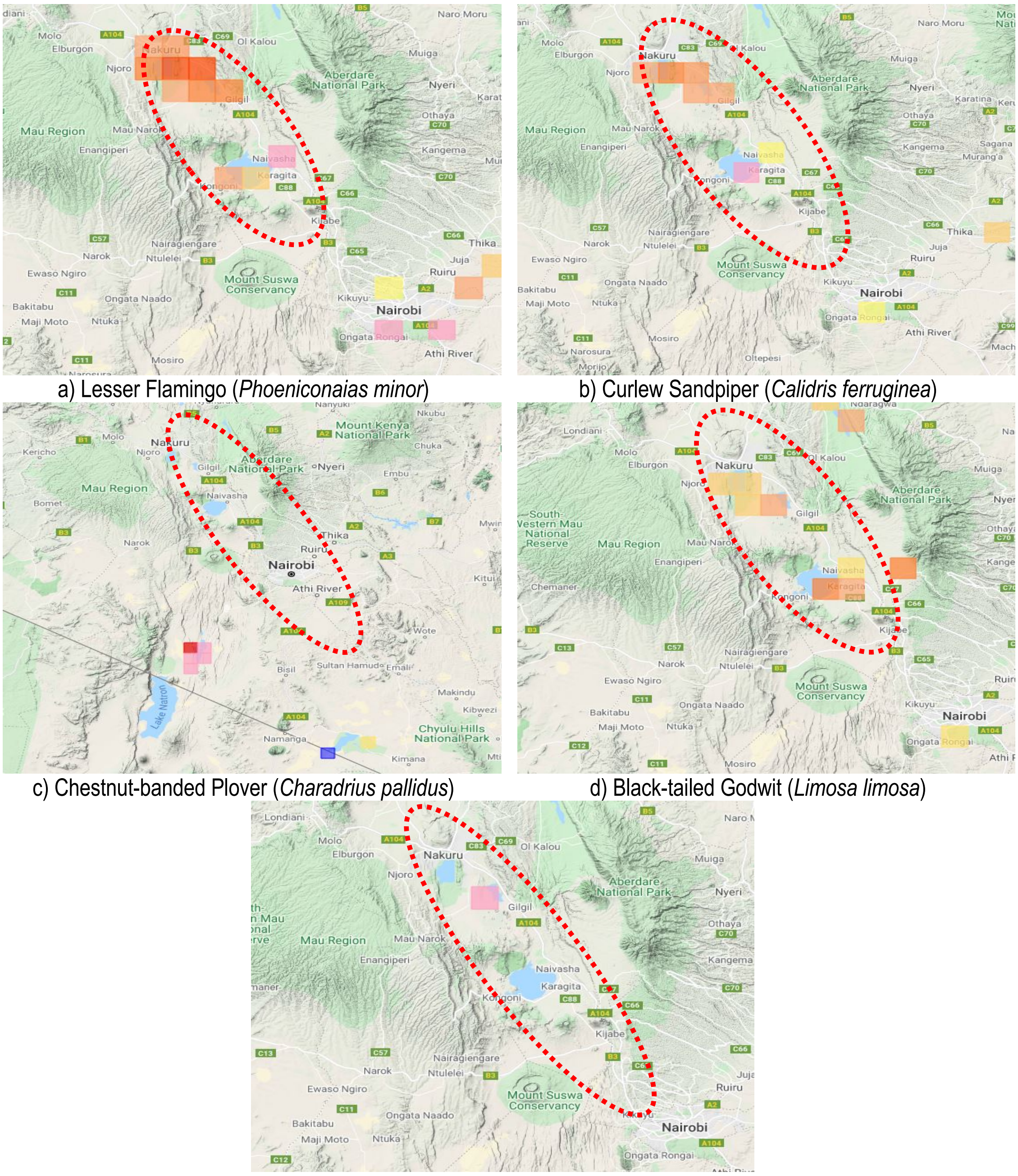
- **Lesser Flamingo (*P. minor*)** - The Lesser Flamingo is globally near threatened (BirdLife International, 2018d) owing to a steady decline of the global population due to soda-ash mining (e.g. at Lake Natron, a major breeding colony for this species in Tanzania), habitat degradation, human disturbances and collisions with powerlines.

  During the survey, large congregations of several hundred to thousands of foraging birds were observed from the shoreline of Lake Elmenteita on the survey area. The number of birds increased significantly during the April survey which coincided with a decrease in the lake's water levels.

- **Curlew Sandpiper (*C. ferruginea*)** - The Curlew Sandpiper was recently uplisted to near threatened owing to a decline in the global population which approached the threshold for the Vulnerable category (BirdLife International, 2017b). However, the sub-population using the East Asian - Australasian Flyway is believed to be experiencing severe declines due to habitat loss in the Yellow Sea. It has also experienced short-term declines in West Africa at key staging points (stop-over points) during migration such as Banc d'Argiun (Mauritania) and Bijagos (Guinea Bissau) between 2003 and 2014. In Kenya, it may be threatened by habitat loss and wetland degradation.

  Large numbers (>100 individuals) were observed foraging along the shoreline of Lake Elmenteita, where it is believed to be a regular non-breeding visitor to the lake's shoreline during the austral summer.

- **Chestnut-banded Plover (*C. pallidus*)** - The Chestnut-banded Plover is probably an overlooked or irregular foraging visitor to Lake Elmenteita. A single observation (representing a single individual) was observed from the shoreline of Lake Elmenteita in April 2021.



a) Lesser Flamingo (*Phoeniconaias minor*)

b) Curlew Sandpiper (*Calidris ferruginea*)

c) Chestnut-banded Plover (*Charadrius pallidus*)

d) Black-tailed Godwit (*Limosa limosa*)

c) Eurasian Curlew (*Numenius arquata*)

Figure 43: The distribution range of near threatened waterbird and shorebird species relative the survey area according to the Kenya Bird Map. The stippled oval shows the approximate position of the Regional Assessment Area.

Figure 44: An example of (a-b) Lesser Flamingo (*Phoeniconaias minor*) and (c-d) Curlew Sandpiper (*Calidris ferruginea*) observed during the surveys at Lake Elmenteita.

6.5.1.6. Notes on species with a high probability of occurrence

The following species were not observed during the respective survey campaigns, although it is of the opinion that these species could occur on specific habitat units on or in close proximity to the survey area:

- **Madagascar Pond-heron (*Ardeola idea*) -** The Madagascar Pond Heron is an endangered migratory species (BirdLife International, 2016g) with an estimated global population size between 2,000 – 6,000 individuals (Delany and Scott, 2002). This species is a non-breeding winter visitor (July - September) to East Africa where it prefers well vegetated freshwater pools and ponds. It breeds on Madagascar, as well as Aldabra, the Seychelles and the Comoros, with the core of the population breeding on Madagascar (BirdLife International, 2016g).

  According to the Kenya Bird Map, there are no recent records of this species on the survey area (Figure 45). However, anecdotal evidence of this species has been reported from wetland habitat with dense marginal vegetation at Lake Elmenteita within the Soysambu Conservancy (pers. comm; Mr Henry Ole

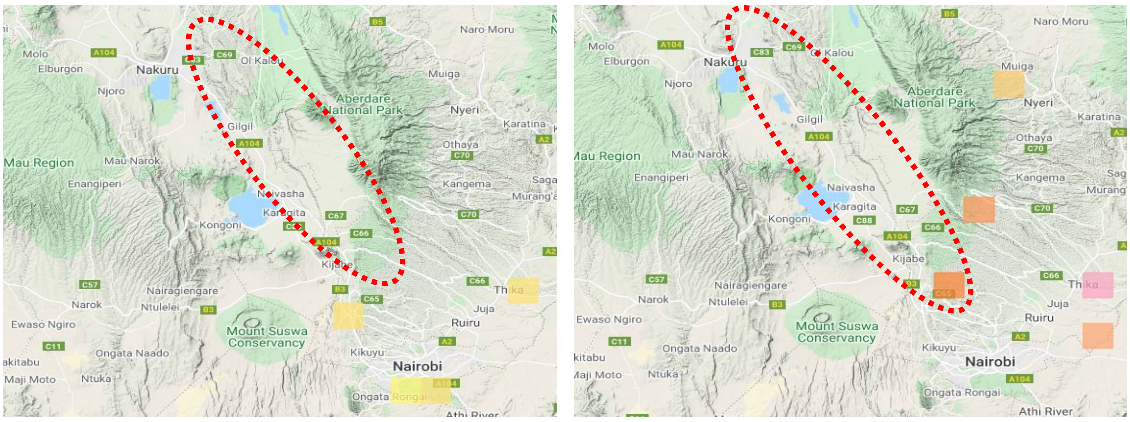
Sanoe, Soysambu Conservancy). This particular area consists of a freshwater seep draining the lake system which provided dense marginal foraging habitat for this species to be present. In addition, the inundated marginal vegetation at Mangou Pond also provides optimal habitat for this species to be present during the austral dry season[11]. Although no pond-herons was observed during the survey campaigns (since this species is an austral winter visitor) it is of the opinion that optimal foraging habitat occurs on the survey area, and may have been overlooked by citizen scientists in the area[12].

- **Abbott's Starling (*Poeoptera femoralis*) -** The Abbott's Starling is a vulnerable forest species (BirdLife International, 2016h) with an extremely small range confined to Afromontane forest in Kenya and Tanzania, with the core of the population occurring in the Kikuyu Escarpment Forest (Figure 45). It also makes long-distance movements between forest patches in search of fruiting trees (Zimmerman et al., 2005).

  The Abbott's Starling was not observed in the survey area during the surveys although suspected to be present in the Kinale forest, which forms part of the Kikuyu Escarpment Forest. It often co-occurs with other forest starlings such as Sharpe's Starling (*Pholia sharpei*) and Waller's Starling (*Onychognathus walleri*) ((Zimmerman et al., 2005). Therefore, all intact forest patches, with reference to large late-successional forest patches provide potential ephemeral foraging habitat for Abbott's Starling. In addition, Sharpe's Starling (*Pholia sharpei*) and Waller's Starling (*Onychognathus walleri*) was observed in large AfmB forest, suggesting that this species could occur on the survey area.

[11] The author is experienced in identifying suitable Madagascar Pond-heron (*Ardeola idea*) habitat and took part in a monitoring programme and biodiversity impact assessments at the Cabo del Cado Province in northern Mozambique where this species was identified and where counts of this species of took place on an annual basis.

[12] The Madagascar Pond-heron (*Ardeola idea*) is a cryptic species and difficult to observe within its habitat, where it is often concealed within marginal vegetation. Its presence is only revealed by "flushing" individuals while walking along suitable habitat, which may explain the low reporting rates of this species in Kenya. It is also easily confused with the sympatric Common Squacco Heron (*A. ralloides*).



a) Madagascar Pond-heron (*Ardeola idea*) b) Abbott's Starling (*Poeoptera femoralis*)

Figure 45: The extant distribution range of (a) Madagascar Pond-heron (*Ardeola idea*) and Abbott's Starling (*Poeoptera femoralis*) relative the survey area according to the Kenya Bird Map. The stippled oval shows the approximate position of the Regional Assessment Area.

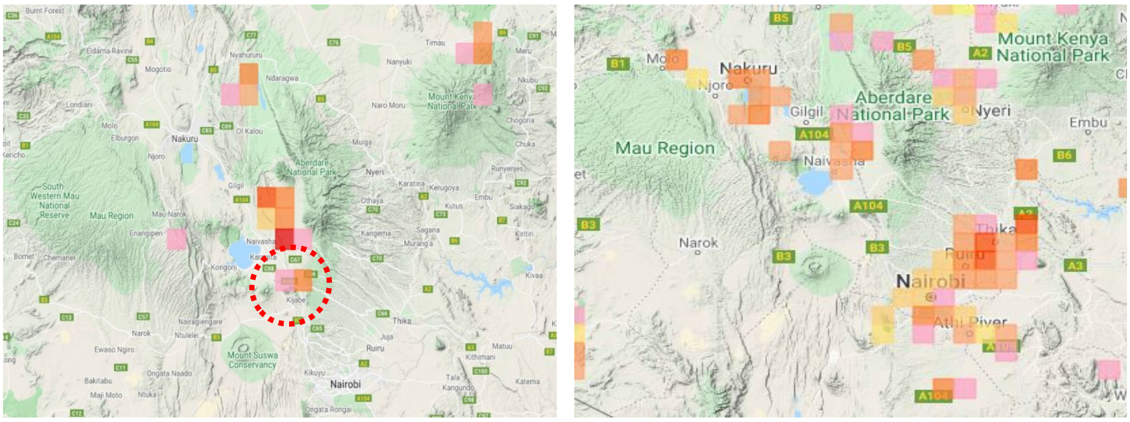
6.5.1.7. Notes on the probability of occurrence of Sharpe's Longclaw (Macronyx sharpei)

The Sharpe's Longclaw is endemic to Kenya and classified as engendered since the global population is experiencing a decline in number owing to a continuous reduction in its habitat quality (BirdLife International, 2016i**)**. The distribution range of the global population is also highly fragmented, with the two sub-population clusters located at Mau Narok and the high altitude grasslands on the north and north-eastern side of Mount Kenya.

The Kinangop grasslands, which is located in close proximity to the survey area was once regarded as a stronghold for the global population, but this area has undergone extensive habitat destruction to the extent that it no longer holds significant numbers of this species (BirdLife International, 2016i), where grassland habitat is converted to cultivation and plantations by small-scale farmers (Muchai, 1998; Lens et. al., 2000; Muchai et al., 2002). In addition, most farmers in the Kinangop area is also converting land from a pastoral system to agriculture, meaning that suitable tussock grassland is converted to arable land. In areas where a pastoral system is still used, the heavy grazing by livestock resulted in open, short grassland that is unsuitable for *M. sharpei* (Rayment and Pisano, 1999). In other areas within its distribution range, its habitat is threatened by bush encroachment due to a lack of grazing and fires.

It was recently observed (c. 21 April 2021) from two pentad grids that are sympatric to the Regional Assessment Area (according to the Kenya Bird Map; Figure 46), although it is of the opinion that these birds were observed on higher lying grassland patches that are located outside of the Local Assessment Area. These pentad grids also overlap with the Thika-Mango Flyover grasslands. The possibility also exists that these observations were erroneous and may have been confused with the sympatric Yellow-throated Longclaw (*M. croceus*) which also occurs in the survey area (Figure 46), thereby emphasising the importance of a rigorous vetting system before records are accepted by the atlas committee.

This species was searched for at several grassland patches within the Local Assessment Area, including the Thika-Mango Flyover grasslands, but was not confirmed during the survey campaigns. Given the degraded condition (overgrazed short grassland) of these grassland patches, especially due to persistent disturbances and trampling caused by livestock (sometimes several hundred individuals of sheep and cattle were observed on relatively small patches of grassland) and by human activities), the probability that this species occurs on the physical impact zone of the Local Assessment Area (e.g. approximately 100 m on either side of the road reserve) is low.



a) Sharpe's Longclaw (*Macronyx sharpei*) b) Yellow-throated Longclaw (*Macronyx croceus*)

Figure 46: The extant distribution range of (a) Sharpe's Longclaw (*Macronyx sharpei*) and Yellow-throated Longclaw (*M. croceus*) in central Kenya according to the Kenya Bird Map. The stippled circle shows two pentad grids which overlap with the survey area where *S. sharpei* was recently observed.

6.6. Species Richness and Habitat Specialisation

The highest number of species was observed from the Afromontane Undifferentiated forest (AUF) with 189 species recorded, followed by the Evergreen and semi-evergreen bushland and thicket (ESEBT) habitat with 185 species recorded and the Riparian Wooded Vegetation (RWV) with 137 species recorded. Low richness values were observed from the Edaphic Wooded Grassland (EWG) with 48 species recorded when compared to the other habitat types. The survey area traverses an altitudinal gradient which includes various forest and grassland habitat at higher altitudes, which then gives way to woodland and bushland habitat at lower altitudes within the Rift Valley. In addition, bird richness is further amplified by modifying these habitat types (e.g. anthropogenic disturbances, grazing and fallow land) which are often colonised by forest edge and generalist woodland birds, while through ecological succession a suite of bird species are prevalent which includes both pioneer and secondary species at the one extreme to forest -interior taxa at the other extreme. The bird richness is further elevated by a composition confined to wetland and aquatic habitat types, even though the alpha-diversity at these habitat types (e.g. EWG) was low. It reiterates the inter-specific habitat specialisation of bird taxa among each other and the floristic structure of the dominant habitat.

6.7. Succession

The survey area is located along a busy highway where land transformation and human-induced activities is a common feature. Therefore, a successional continuum is prevalent from the road reserve to the outer boundary of the survey area, with a high prevalence of habitat at secondary and pioneer ecological condition occurring near or alongside the A8 highway and more intact habitat further away from the road reserve. The Afromontane Undifferentiated Forest (AUF) was prominent along the road, especially along the higher escarpment of the Rift Valley, although also subject to various human-induced transformations (e.g. cultivation). This has resulted in a sere of forest patches at different stages of forest regeneration which also hold different bird species with different niches (e.g. forest edge species vs forest interior species), thereby explaining the high richness of bird species prevalent on this habitat units. Similarly, the evergreen and semi-evergreen bushland and thicket habitat show large areas that were cleared of the woody layer to enhance livestock grazing, which also have created secondary habitat for many "grassland" bird species. Grazing by game and fire management practices has also reduced the woody biomass of an essentially woodland habitat which created additional foraging habitat for large terrestrial bird species such as ground-hornbills, Secretarybirds and bustards.

6.8. Guilds

Habitat complexity and guild diversity are proportionally related, which means that habitat with a high membership of guilds will be ecologically diverse and functional. Therefore, habitat types supporting a tall canopy and high spatial heterogeneity, for example Afromontane Undifferentiated Forest and Riparian Wooded Vegetation are likely to have a high membership of functional guilds. These habitat types are also characterised by a high prevalence of fruit-eating species as opposed to granivores which are more prominent in open habitat (e.g. EWG and ESEBT). However, the high vertical heterogeneity of the forest habitat types and Riparian wooded vegetation has contributed to the diversity of insectivorous guilds, which were otherwise less pronounced in the other habitat types.

6.9. Waterbirds

Approximately 149 waterbird species are expected to occur on the survey area, of which 92 species were observed during the survey campaigns (61% of the expected waterbird tally). Many of these species occur in large numbers (e.g. >1000 foraging individuals of Lesser Flamingos *Phoeniconaias minor* occurred along the shoreline of Lake Elmenteita) and are represented by large congregatory flocks of anatids (ducks and geese), Palearctic waders (scolopacid stints and sandpipers and charadriid plovers), cormorants, grebes, pelicans and wading birds represented by herons, egrets and storks. Some sections along the road alignment are especially of interest:

- *Lake Elemeteita*: An Important Bird Area which supports thousands to millions of foraging waterbirds, especially flamingos. It is also an important "staging" or "fuelling" site for Palearctic wader species on passage.
- *Mangou Pond*: An important wetland system that supports high richness of anatid species and breeding habitat for threatened species (e.g. Grey Crowned Crane *Balearica regulorum*). It also supports a high richness of waterbird species in general, and potential winter foraging habitat for the endangered Madagascar Pond-heron (*Ardeola idea*).
- *Marula Estate floodplains*: Some sections of rivers at Marula Estate often overspill during flood events into large floodplains which provide foraging habitat for large numbers of anatid species and Palearctic wader species. These are also important roosting sites for large numbers of roosting Spurwinged Goose (*Plectropterus gambiensis*), Egyptian Goose (*Alopochen aegyptiaca*) and Grey-crowned Crane (*Balearica regulorum*).

6.10. Synthesis

The proposed A8 Highway project traverses an area that is characterised by high topographic complexity (high altitude forest and grassland along the Rift Valley escarpment to woodland in the Rift Valley basin) and floristic structure, which resulted in a high diversity of habitat types located along its alignment. This high habitat and topographic complexity, along with the occurrence of various wetland features are responsible for a high richness of bird species (approximately 600 species are expected with >400 observed), which include many forest-dependant species as well as many threatened, near threatened and congregatory bird species of international importance. However, many of the habitat types, especially forest habitat were also in various ways modified by human-induced disturbances (deforestation, afforestation, grazing and cultivation) which resulted in a vegetation sere that represents a disturbance gradient with floristic elements pertaining to secondary as well as late-successional habitat. This "disturbance gradient" has contributed to the high observed richness in bird species along the highway, which includes specialist forest-dependant species (at the one extreme) to widespread generalist granivore taxa (mainly Ploceid weavers, Passerid sparrow and estrlidinid finches and waxbills at the other extreme).

7. EXPERT STATEMENT ON THE PROBABLE LEVEL OF IMPACT FROM THE ROAD

Bird species are in general highly mobile and therefore less severely impacted by the construction of roads. High mortalities caused by ongoing traffic and moving vehicles are more likely to occur at newly constructed roads, and less so on established roads since residing bird populations tend to become accustomed to impacts that are in general deterministic (predictable). The current project involves the addition of traffic lanes, with the majority of the construction works taking place within the existing road reserve, while some of the construction activities at the larger interchanges will take place outside of the existing road reserve. Therefore, it is anticipated that habitat types located within the impact zone are likely to become lost or reduced due to the broadening of the road surface area. Given that large sections of the habitat that are directly impacted by the alignment are already modified and those that are natural are invariably of secondary condition, it is of the opinion that the probable level of impact from the road on the bird community is moderate to low.

However, some "hotspot" areas do occur in close proximity to the road where widening of the road could potentially result in the loss of important breeding and roosting habitat for threatened and congregatory bird species, such as the Mangou Pond. Therefore avoidance and/or mitigation measures are proposed to either prevent traversing through sensitive habitat types which hold high numbers of congregatory as well a biome-restricted bird species or by applying engineering structures (overpasses and span bridges and effective stormwater dissipating systems) that will ensure the continual functioning of these systems without displacement of the residing bird populations. Potential impact emanating from the widening of the roads will include:

- Loss of habitat and the potential displacement of bird taxa, especially the loss of late-successional forest, wetlands and EWG habitat.
- Temporary displacement of large terrestrial bird species (e.g. cranes, bustards, ground-hornbills and Secretarybirds) due to disturbances along the Marula Estates and Soysambu Conservancies.
- Changes to the inundation levels and water chemistry at proximal wetland and lake systems due to ineffective stormwater management and or increased surface run-off, thereby resulting in the displacement of congregatory bird species of international importance.
- Increased alien plant encroachment at recently disturbed habitat (after construction), thereby resulting in changes to the floristic structure and composition of natural habitat and ultimately resulting in changes to the bird composition (resulting in the loss of avifaunal richness and increased colonization by generalist bird species).

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9. APPENDIX 1

A shortlist of bird species observed and expected to occur on the survey area. Scientific and common names were used according to Gill et all. (2021). Habitat: AfR - Afromontane Rainforest, AUF - Afromontane Undifferentiated Forest, AfmB - Afromontane Bamboo, HalV - Halophytic Vegetation, UAWG - Upper *Acacia* Wooded Grassland, ESEBT- Evergreen and semi-evergreen bushland and thicket, RWV - Riparian Wooded Vegetation and EWG - Edaphic Wooded Grassland.
Also provided is the global conservation status (IUCN, 2021): CR - Critically Endangered, EN - Endangered, VU - Vulnerable, NT - Near threatened) with the following notes on special status:
1. Protected in Kenya - the information was sourced from "The Wildlife Conservation and Management Act, 2013 (no. 47 of 2013)". It also provides an indication of the threatened status of certain birds (although outdated). PROT: protected
2. Fischer's Lovebird (*Agapornis fischeri*) is NT in Tanzania, the observed population in Kenya is regarded as feral birds (not wild populations)
3. Endemic status refers to birds that are endemic to East Africa (shared with Tanzania and Uganda)
4. Under Endemic status - X* - refers to Kikuyu White-eye (*Zosterops kikuyuensis*), the only "true" endemic bird to Kenya that was observed on the survey area (one of 11 species that are Kenyan Endemics)
5. Under Migrants - Status in brackets (P) or (A) implies that part of the population for that species in Kenya is also resident and part thereof is augmented with migratory birds
6. Under Water Birds - Status in brackets (X) refers to birds that are often found near water but may also be found in other habitats (facultative water bird species)
7. Secondary Data - Observations of bird species made by other team members during the two survey campaigns. These include mainly easily identified species as well as species that were captured by means of camera traps.

Family	Species	Common Name	Secondary Data	Expected (not observed during the survey campaigns)	Field Campaign		Habitats where the species was surveyed								Special Status				
					Feb-21	Apr-21	AfR	AUF	HalV	AfmB	RWV	UAWG	ESEBT	EWG	Global IUCN Red list	Protected in Kenya	Endemic	Migrant	Water Birds
Accipitridae	*Accipiter badius*	Shikra			X							X	X						
Accipitridae	*Accipiter melanoleucus*	Black Sparrowhawk			X	X	X			X			X						
Accipitridae	*Accipiter minullus*	Little Sparrowhawk			X	X					X		X						
Accipitridae	*Accipiter ovampensis*	Ovambo Sparrowhawk		X				X			X	X	X						
Accipitridae	*Accipiter rufiventris*	Rufous-breasted Sparrowhawk		X			X	X		X									
Accipitridae	*Accipiter tachiro*	African Goshawk			X	X		X					X						
Accipitridae	*Aquila heliaca*	Eastern Imperial Eagle		X				X					X		VU	VU		P	
Accipitridae	*Aquila nipalensis*	Steppe Eagle			X	X							X		EN			P	

Accipitridae	*Aquila rapax*	Tawny Eagle			X	X							X		VU				
Accipitridae	*Aquila spilogaster*	African Hawk-Eagle			X	X		X					X						
Accipitridae	*Aquila verreauxii*	Verreaux's Eagle				X							X						
Accipitridae	*Aviceda cuculoides*	African Cuckoo-Hawk			X			X											
Accipitridae	*Butastur rufipennis*	Grasshopper Buzzard		X							X		X	X				A	
Accipitridae	*Buteo augur*	Augur Buzzard			X	X	X	X	X		X	X	X	X					
Accipitridae	*Buteo buteo*	Common Buzzard			X	X		X		X		X	X	X				P	
Accipitridae	*Buteo oreophilus*	Mountain Buzzard			X	X	X	X		X					NT				
Accipitridae	*Buteo rufinus*	Long-legged Buzzard		X									X					P	
Accipitridae	*Circaetus cinerascens*	Western Banded Snake Eagle		X									X						
Accipitridae	*Circaetus cinereus*	Brown Snake Eagle			X								X						
Accipitridae	*Circaetus pectoralis*	Black-chested Snake Eagle			X								X						
Accipitridae	*Circus aeruginosus*	Western Marsh Harrier			X				X									P	X
Accipitridae	*Circus macrourus*	Pallid Harrier			X			X							NT	NT		P	
Accipitridae	*Circus pygargus*	Montagu's Harrier		X					X					X				P	(X)
Accipitridae	*Circus ranivorus*	African Marsh Harrier			X				X										X
Accipitridae	*Clanga pomarina*	Lesser Spotted Eagle			X	X							X					P	
Accipitridae	*Elanus caeruleus*	Black-winged Kite			X	X							X						
Accipitridae	*Gypaetus barbatus*	Bearded Vulture		X			X	X		X					NT				
Accipitridae	*Gyps africanus*	White-backed Vulture			X								X		CR	NT			
Accipitridae	*Gyps rueppelli*	Rüppell's Vulture			X	X					X		X		CR	NT			
Accipitridae	*Haliaeetus vocifer*	African Fish Eagle			X	X					X					PROT			X
Accipitridae	*Hieraaetus ayresii*	Ayres's Hawk-Eagle		X			X	X		X						PROT			
Accipitridae	*Hieraaetus pennatus*	Booted Eagle		X				X				X	X					P	
Accipitridae	*Hieraaetus wahlbergi*	Wahlberg's Eagle			X	X						X	X					A	
Accipitridae	*Kaupifalco monogrammicus*	Lizard Buzzard			X						X		X						

Accipitridae	*Lophaetus occipitalis*	Long-crested Eagle			X	X	X	X				X	X						
Accipitridae	*Macheiramphus alcinus*	Bat Hawk		X			X	X		X	X	X	X						
Accipitridae	*Melierax metabates*	Dark Chanting Goshawk			X								X						
Accipitridae	*Micronisus gabar*	Gabar Goshawk			X	X						X	X						
Accipitridae	*Milvus aegyptius*	Yellow-billed Kite			X	X	X	X	X	X	X	X	X	X				A	
Accipitridae	*Milvus migrans*	Black Kite		X			X	X	X	X	X	X	X	X				P	
Accipitridae	*Necrosyrtes monachus*	Hooded Vulture		X									X		CR				
Accipitridae	*Neophron percnopterus*	Egyptian Vulture		X									X		EN	EN			
Accipitridae	*Pernis apivorus*	European Honey Buzzard				X							X					P	
Accipitridae	*Polemaetus bellicosus*	Martial Eagle			X						X				EN	PROT			
Accipitridae	*Polyboroides typus*	African Harrier-Hawk			X	X			X		X		X						
Accipitridae	*Stephanoaetus coronatus*	Crowned Eagle				X	X				X				NT	PROT			
Accipitridae	*Terathopius ecaudatus*	Bateleur	X		X								X		EN				
Accipitridae	*Torgos tracheliotos*	Lappet-faced Vulture		X									X		EN	VU			
Acrocephalidae	*Acrocephalus arundinaceus*	Great Reed Warbler		X					X					X				P	X
Acrocephalidae	*Acrocephalus gracilirostris*	Lesser Swamp Warbler			X	X		X						X					X
Acrocephalidae	*Acrocephalus griseldis*	Basra Reed Warbler		X					X		X				EN	EN		P	(X)
Acrocephalidae	*Acrocephalus palustris*	Marsh Warbler			X			X										P	
Acrocephalidae	*Acrocephalus schoenobaenus*	Sedge Warbler				X			X									P	X
Acrocephalidae	*Acrocephalus scirpaceus*	Eurasian Reed Warbler				X			X									P	X
Acrocephalidae	*Hippolais icterina*	Icterine Warbler		X									X					P	
Acrocephalidae	*Iduna natalensis*	African Yellow Warbler			X	X		X				X	X						
Acrocephalidae	*Iduna pallida*	Eastern Olivaceous Warbler		X								X	X					P	
Acrocephalidae	*Iduna similis*	Mountain Yellow Warbler			X	X	X	X		X									
Alaudidae	*Calandrella cinerea*	Red-capped Lark			X	X			X				X						
Alaudidae	*Calendulauda alopex*	Foxy Lark			X	X					X								

Alaudidae	*Eremopterix leucopareia*	Fischer's Sparrow-Lark				X							X						
Alaudidae	*Eremopterix leucotis*	Chestnut-backed Sparrow-Lark		X									X						
Alaudidae	*Mirafra africana*	Rufous-naped Lark			X	X		X			X		X						
Alaudidae	*Mirafra albicauda*	White-tailed Lark				X							X						
Alaudidae	*Mirafra cantillans*	Singing Bush Lark				X							X						
Alcedinidae	*Ceryle rudis*	Pied Kingfisher			X	X			X										X
Alcedinidae	*Corythornis cristatus*	Malachite Kingfisher			X						X								X
Alcedinidae	*Halcyon chelicuti*	Striped Kingfisher			X	X							X						
Alcedinidae	*Halcyon leucocephala*	Grey-headed Kingfisher			X								X					(P)	
Alcedinidae	*Ispidina picta*	African Pygmy Kingfisher		X							X		X					(A)	
Alcedinidae	*Megaceryle maxima*	Giant Kingfisher			X	X		X	X		X	X							X
Anatidae	*Alaudala athensis*	Athi Short-toed Lark		X									X						
Anatidae	*Alopochen aegyptiaca*	Egyptian Goose			X	X		X	X		X		X						X
Anatidae	*Anas acuta*	Northern Pintail		X					X					X				P	X
Anatidae	*Anas capensis*	Cape Teal			X	X			X										X
Anatidae	*Anas crecca*	Eurasian Teal		X					X					X				P	X
Anatidae	*Anas erythrorhyncha*	Red-billed Teal			X	X		X											X
Anatidae	*Anas sparsa*	African Black Duck			X			X		X	X		X						X
Anatidae	*Anas undulata*	Yellow-billed Duck			X	X		X			X			X					X
Anatidae	*Aythya fuligula*	Tufted Duck		X					X					X				P	X
Anatidae	*Dendrocygna bicolor*	Fulvous Whistling Duck			X			X										(A)	X
Anatidae	*Dendrocygna viduata*	White-faced Whistling Duck			X	X		X											X
Anatidae	*Netta erythrophthalma*	Southern Pochard		X					X					X				(A)	X
Anatidae	*Plectropterus gambensis*	Spur-winged Goose			X			X	X		X			X					X
Anatidae	*Sarkidiornis melanotos*	Knob-billed Duck			X				X		X		X						X
Anatidae	*Spatula clypeata*	Northern Shoveler		X					X					X				P	X

Anatidae	*Spatula hottentota*	Blue-billed Teal			X	X		X	X		X								X
Anatidae	*Spatula querquedula*	Garganey		X					X					X				P	X
Anatidae	*Thalassornis leuconotus*	White-backed Duck			X			X											X
Anhingidae	*Anhinga rufa*	African Darter				X			X					X		PROT			X
Apodidae	*Apus affinis*	Little Swift			X	X			X		X		X						
Apodidae	*Apus apus*	Common Swift			X	X		X			X		X					P	
Apodidae	*Apus barbatus*	African Black Swift			X	X		X					X						
Apodidae	*Apus caffer*	White-rumped Swift			X	X		X	X				X						
Apodidae	*Apus horus*	Horus Swift			X	X		X					X					A	
Apodidae	*Apus niansae*	Nyanza Swift			X	X		X	X	X	X		X			PROT			
Apodidae	*Cypsiurus parvus*	African Palm Swift			X	X		X	X										
Apodidae	*Schoutedenapus myoptilus*	Scarce Swift			X	X		X					X						
Apodidae	*Tachymarptis aequatorialis*	Mottled Swift			X			X	X				X						
Apodidae	*Tachymarptis melba*	Alpine Swift				X		X										(P)	
Ardeidae	*Ardea alba*	Great Egret			X	X			X		X					PROT			X
Ardeidae	*Ardea cinerea*	Grey Heron			X	X		X			X								X
Ardeidae	*Ardea goliath*	Goliath Heron		X					X					X					X
Ardeidae	*Ardea intermedia*	Intermediate Egret			X	X		X			X								X
Ardeidae	*Ardea melanocephala*	Black-headed Heron			X	X		X				X	X	X					X
Ardeidae	*Ardea purpurea*	Purple Heron			X	X								X					X
Ardeidae	*Ardeola idae*	Malagasy Pond Heron		X					X					X	EN	EN		A	X
Ardeidae	*Ardeola ralloides*	Squacco Heron			X	X			X										X
Ardeidae	*Bubulcus ibis*	Western Cattle Egret			X	X			X		X		X	X					(X)
Ardeidae	*Butorides striata*	Striated Heron		X					X		X			X					X
Ardeidae	*Egretta ardesiaca*	Black Heron		X					X					X					X
Ardeidae	*Egretta garzetta*	Little Egret			X	X			X										X

Ardeidae	*Ixobrychus minutus*	Little Bittern		X					X					X				(P)	X
Ardeidae	*Ixobrychus sturmii*	Dwarf Bittern		X					X									(A)	X
Ardeidae	*Nycticorax nycticorax*	Black-crowned Night Heron			X	X			X	X	X								X
Bucerotidae	*Bycanistes brevis*	Silvery-cheeked Hornbill				X	X	X		X									
Bucerotidae	*Bycanistes bucinator*	Trumpeter Hornbill		X				X		X	X								
Bucerotidae	*Lophoceros alboterminatus*	Crowned Hornbill			X	X	X		X				X						
Bucerotidae	*Lophoceros nasutus*	African Grey Hornbill			X	X					X								
Bucerotidae	*Tockus erythrorhynchus*	Northern Red-billed Hornbill		X									X						
Bucorvidae	*Bucorvus leadbeateri*	Southern Ground Hornbill			X								X		VU				
Buphagidae	*Buphagus africanus*	Yellow-billed Oxpecker		X									X			PROT			
Buphagidae	*Buphagus erythrorynchus*	Red-billed Oxpecker			X	X					X		X			PROT			
Burhinidae	*Burhinus capensis*	Spotted Thick-knee			X	X							X						
Burhinidae	*Burhinus vermiculatus*	Water Thick-knee		X					X		X								X
Campephagidae	*Campephaga flava*	Black Cuckooshrike			X	X					X		X					(A)	
Campephagidae	*Campephaga quiscalina*	Purple-throated Cuckooshrike			X	X		X											
Campephagidae	*Ceblepyris caesius*	Grey Cuckooshrike			X	X	X	X		X									
Caprimulgidae	*Caprimulgus clarus*	Slender-tailed Nightjar		X									X						
Caprimulgidae	*Caprimulgus europaeus*	European Nightjar		X				X			X	X	X					P	
Caprimulgidae	*Caprimulgus fraenatus*	Sombre Nightjar			X			X											
Caprimulgidae	*Caprimulgus inornatus*	Plain Nightjar		X									X					A	
Caprimulgidae	*Caprimulgus poliocephalus*	Montane Nightjar			X	X		X											
Caprimulgidae	*Caprimulgus tristigma*	Freckled Nightjar		X				X					X						
Charadriidae	*Charadrius alexandrinus*	Kentish Plover				X			X									P	X
Charadriidae	*Charadrius asiaticus*	Caspian Plover		X					X									P	X
Charadriidae	*Charadrius dubius*	Little Ringed Plover			X				X		X							P	X
Charadriidae	*Charadrius hiaticula*	Common Ringed Plover			X	X			X									P	X

Charadriidae	*Charadrius leschenaultii*	Greater Sand Plover				X			X									P	X
Charadriidae	*Charadrius mongolus*	Lesser Sand Plover				X			X									P	X
Charadriidae	*Charadrius pallidus*	Chestnut-banded Plover	X			X			X						NT	NT			X
Charadriidae	*Charadrius pecuarius*	Kittlitz's Plover			X	X			X										X
Charadriidae	*Charadrius tricollaris*	Three-banded Plover			X	X			X		X			X					X
Charadriidae	*Pluvialis squatarola*	Grey Plover		X					X									P	X
Charadriidae	*Vanellus armatus*	Blacksmith Lapwing			X	X		X	X		X		X	X					X
Charadriidae	*Vanellus coronatus*	Crowned Lapwing			X	X					X		X						
Charadriidae	*Vanellus crassirostris*	Long-toed Lapwing		X					X					X					X
Charadriidae	*Vanellus lugubris*	Senegal Lapwing			X	X		X			X		X						
Charadriidae	*Vanellus melanopterus*	Black-winged Lapwing			X	X		X					X						
Charadriidae	*Vanellus spinosus*	Spur-winged Lapwing			X	X			X		X								(X)
Ciconiidae	*Anastomus lamelligerus*	African Openbill		X					X					X					X
Ciconiidae	*Ciconia abdimii*	Abdim's Stork			X	X							X					A	
Ciconiidae	*Ciconia ciconia*	White Stork			X	X		X			X	X	X					P	
Ciconiidae	*Ciconia episcopus*	Woolly-necked Stork		X					X		X		X						(X)
Ciconiidae	*Ciconia nigra*	Black Stork		X				X	X				X	X				P	(X)
Ciconiidae	*Ephippiorhynchus senegalensis*	Saddle-billed Stork				X					X					PROT			X
Ciconiidae	*Leptoptilos crumenifer*	Marabou Stork			X	X		X	X		X		X						
Ciconiidae	*Mycteria ibis*	Yellow-billed Stork			X	X		X	X		X		X						X
Cisticolidae	*Apalis cinerea*	Grey Apalis			X	X	X	X		X									
Cisticolidae	*Apalis flavida*	Yellow-breasted Apalis			X	X		X	X		X	X	X						
Cisticolidae	*Apalis jacksoni*	Black-throated Apalis				X	X												
Cisticolidae	*Apalis melanocephala*	Black-headed Apalis		X				X											
Cisticolidae	*Apalis porphyrolaema*	Chestnut-throated Apalis			X	X	X	X		X									
Cisticolidae	*Camaroptera brevicaudata*	Grey-backed Camaroptera			X	X		X	X	X	X	X	X						

Cisticolidae	*Cisticola aridulus*	Desert Cisticola				X		X					X						
Cisticolidae	*Cisticola ayresii*	Wing-snapping Cisticola		X										X					
Cisticolidae	*Cisticola brachypterus*	Short-winged Cisticola				X							X						
Cisticolidae	*Cisticola brunnescens*	Pectoral-patch Cisticola				X						X	X						
Cisticolidae	*Cisticola cantans*	Singing Cisticola			X	X		X					X						
Cisticolidae	*Cisticola chiniana*	Rattling Cisticola			X	X		X	X		X	X	X						
Cisticolidae	*Cisticola distinctus*	Lynes's Cisticola			X			X					X						
Cisticolidae	*Cisticola erythrops*	Red-faced Cisticola			X	X						X							
Cisticolidae	*Cisticola hunteri*	Hunter's Cisticola			X	X	X	X		X			X	X			X		
Cisticolidae	*Cisticola juncidis*	Zitting Cisticola				X						X	X						
Cisticolidae	*Cisticola marginatus*	Winding Cisticola			X	X			X		X	X		X					X
Cisticolidae	*Cisticola natalensis*	Croaking Cisticola			X	X							X						
Cisticolidae	*Cisticola robustus*	Stout Cisticola				X						X	X						
Cisticolidae	*Cisticola tinniens*	Levaillant's Cisticola			X	X								X					
Cisticolidae	*Eminia lepida*	Grey-capped Warbler			X	X	X	X	X	X	X	X	X						
Cisticolidae	*Eremomela icteropygialis*	Yellow-bellied Eremomela			X	X							X						
Cisticolidae	*Eremomela scotops*	Green-capped Eremomela		X									X						
Cisticolidae	*Oreolais pulcher*	Black-collared Apalis			X	X	X	X					X						
Cisticolidae	*Phyllolais pulchella*	Buff-bellied Warbler			X	X		X	X		X	X	X						
Cisticolidae	*Prinia subflava*	Tawny-flanked Prinia			X	X		X			X	X	X	X					
Coliidae	*Colius striatus*	Speckled Mousebird			X	X		X	X	X	X	X	X						
Coliidae	*Urocolius macrourus*	Blue-naped Mousebird			X	X					X		X						
Columbidae	*Columba arquatrix*	African Olive Pigeon		X				X		X									
Columbidae	*Columba delegorguei*	Eastern Bronze-naped Pigeon		X			X	X		X									
Columbidae	*Columba guinea*	Speckled Pigeon			X	X							X						
Columbidae	*Columba larvata*	Lemon Dove			X	X	X	X											

Columbidae	*Columba livia*	Rock Dove			X	X							X						
Columbidae	*Oena capensis*	Namaqua Dove			X								X						
Columbidae	*Spilopelia senegalensis*	Laughing Dove			X	X		X			X		X						
Columbidae	*Streptopelia capicola*	Ring-necked Dove			X	X		X	X		X	X	X	X					
Columbidae	*Streptopelia decipiens*	Mourning Collared Dove		X								X	X						
Columbidae	*Streptopelia lugens*	Dusky Turtle Dove			X	X		X			X		X						
Columbidae	*Streptopelia semitorquata*	Red-eyed Dove			X	X		X	X		X	X	X	X					
Columbidae	*Treron calvus*	African Green Pigeon			X	X		X											
Columbidae	*Turtur chalcospilos*	Emerald-spotted Wood Dove			X	X		X	X		X	X	X						
Columbidae	*Turtur tympanistria*	Tambourine Dove			X	X		X					X						
Coraciidae	*Coracias caudatus*	Lilac-breasted Roller			X	X			X		X		X						
Coraciidae	*Coracias garrulus*	European Roller	X			X							X			NT		P	
Coraciidae	*Coracias naevius*	Purple Roller				X					X								
Coraciidae	*Eurystomus glaucurus*	Broad-billed Roller				X					X		X					A	
Corvidae	*Corvus albicollis*	White-necked Raven		X				X		X									
Corvidae	*Corvus albus*	Pied Crow			X	X	X	X		X		X	X	X					
Corvidae	*Corvus capensis*	Cape Crow			X	X		X		X			X	X					
Cuculidae	*Centropus grillii*	Black Coucal		X										X					(X)
Cuculidae	*Centropus monachus*	Blue-headed Coucal		X			X												(X)
Cuculidae	*Centropus superciliosus*	White-browed Coucal			X	X		X	X		X	X	X						
Cuculidae	*Ceuthmochares aereus*	Blue Malkoha		X			X	X		X									
Cuculidae	*Chrysococcyx caprius*	Diederik Cuckoo			X	X		X			X	X	X					A	
Cuculidae	*Chrysococcyx cupreus*	African Emerald Cuckoo			X	X	X	X	X	X			X						
Cuculidae	*Chrysococcyx klaas*	Klaas's Cuckoo			X	X		X			X		X					A	
Cuculidae	*Clamator glandarius*	Great Spotted Cuckoo		X									X					A	
Cuculidae	*Clamator jacobinus*	Jacobin Cuckoo		X									X					A	

Cuculidae	*Clamator levaillantii*	Levaillant's Cuckoo		X									X					A	
Cuculidae	*Clanga clanga*	Greater Spotted Eagle		X									X		VU	VU		P	
Cuculidae	*Cuculus canorus*	Common Cuckoo				X				X	X							P	
Cuculidae	*Cuculus clamosus*	Black Cuckoo				X					X							A	
Cuculidae	*Cuculus gularis*	African Cuckoo			X								X					A	
Cuculidae	*Cuculus rochii*	Madagascan Cuckoo		X			X	X		X								A	
Cuculidae	*Cuculus solitarius*	Red-chested Cuckoo			X	X		X			X		X					A	
Dicruridae	*Dicrurus adsimilis*	Fork-tailed Drongo			X	X		X	X		X		X						
Emberizidae	*Emberiza flaviventris*	Golden-breasted Bunting			X	X					X		X						
Emberizidae	*Emberiza poliopleura*	Somali Bunting				X							X						
Emberizidae	*Emberiza tahapisi*	Cinnamon-breasted Bunting			X			X											
Estrildidae	*Amadina fasciata*	Cut-throat Finch			X	X							X						
Estrildidae	*Amandava subflava*	Orange-breasted Waxbill		X					X					X					
Estrildidae	*Coccopygia quartinia*	Yellow-bellied Waxbill			X	X	X	X		X									
Estrildidae	*Cryptospiza salvadorii*	Abyssinian Crimsonwing			X	X	X	X		X									
Estrildidae	*Estrilda astrild*	Common Waxbill			X	X	X	X	X	X	X	X	X	X					
Estrildidae	*Estrilda kandti*	Kandt's Waxbill			X	X	X	X	X				X						
Estrildidae	*Estrilda rhodopyga*	Crimson-rumped Waxbill			X			X											
Estrildidae	*Euodice cantans*	African Silverbill		X									X						
Estrildidae	*Granatina ianthinogaster*	Purple Grenadier			X	X		X	X		X		X						
Estrildidae	*Lagonosticta rhodopareia*	Jameson's Firefinch			X	X			X				X						
Estrildidae	*Lagonosticta rubricata*	African Firefinch			X	X		X											
Estrildidae	*Lagonosticta senegala*	Red-billed Firefinch			X	X		X	X			X							
Estrildidae	*Mandingoa nitidula*	Green Twinspot		X			X	X		X									
Estrildidae	*Nigrita canicapillus*	Grey-headed Nigrita			X	X		X			X								
Estrildidae	*Ortygospiza atricollis*	Quailfinch			X	X						X	X						

Estrildidae	*Pytilia afra*	Orange-winged Pytilia				X							X						
Estrildidae	*Pytilia melba*	Green-winged Pytilia			X	X							X						
Estrildidae	*Spermestes cucullata*	Bronze Mannikin			X	X		X				X	X						
Estrildidae	*Spermestes griseicapilla*	Grey-headed Silverbill				X							X						
Estrildidae	*Spermestes nigriceps*	Red-backed Mannikin		X			X	X		X									
Estrildidae	*Uraeginthus bengalus*	Red-cheeked Cordon-bleu			X	X		X	X		X	X	X						
Falconidae	*Falco amurensis*	Amur Falcon			X	X						X	X					P	
Falconidae	*Falco biarmicus*	Lanner Falcon			X	X							X						
Falconidae	*Falco chicquera*	Red-necked Falcon		X									X						
Falconidae	*Falco concolor*	Sooty Falcon				X							X		VU	NT		P	
Falconidae	*Falco cuvierii*	African Hobby		X							X	X	X						
Falconidae	*Falco naumanni*	Lesser Kestrel		X									X	X		VU		P	
Falconidae	*Falco peregrinus*	Peregrine Falcon		X			X	X		X								(P)	
Falconidae	*Falco rupicoloides*	Greater Kestrel		X									X						
Falconidae	*Falco subbuteo*	Eurasian Hobby				X		X					X					P	
Falconidae	*Falco tinnunculus*	Common Kestrel			X	X							X					(P)	
Fringillidae	*Crithagra buchanani*	Southern Grosbeak-Canary			X	X			X		X						X		
Fringillidae	*Crithagra burtoni*	Thick-billed Seedeater			X	X	X	X	X										
Fringillidae	*Crithagra citrinelloides*	African Citril			X	X	X	X	X	X	X	X	X	X					
Fringillidae	*Crithagra dorsostriata*	White-bellied Canary			X	X							X						
Fringillidae	*Crithagra reichenowi*	Reichenow's Seedeater			X	X		X				X	X						
Fringillidae	*Crithagra striolata*	Streaky Seedeater			X	X	X	X	X	X		X	X	X					
Fringillidae	*Crithagra sulphurata*	Brimstone Canary			X	X		X	X		X	X	X						
Fringillidae	*Serinus flavivertex*	Yellow-crowned Canary			X	X	X	X	X	X		X	X	X					
Glareolidae	*Cursorius temminckii*	Temminck's Courser			X	X							X						
Glareolidae	*Glareola pratincola*	Collared Pratincole		X					X					X				P	(X)

Glareolidae	*Rhinoptilus chalcopterus*	Bronze-winged Courser		X									X						
Gruidae	*Balearica regulorum*	Grey Crowned Crane			X	X		X			X			X	EN	PROT			(X)
Hirundinidae	*Cecropis abyssinica*	Lesser Striped Swallow			X			X											
Hirundinidae	*Cecropis daurica*	Red-rumped Swallow			X	X	X	X	X	X	X		X	X					
Hirundinidae	*Cecropis semirufa*	Red-breasted Swallow			X								X						
Hirundinidae	*Cecropis senegalensis*	Mosque Swallow				X		X											
Hirundinidae	*Delichon urbicum*	Common House Martin			X	X		X	X	X		X	X					P	
Hirundinidae	*Hirundo angolensis*	Angolan Swallow				X		X	X			X							
Hirundinidae	*Hirundo rustica*	Barn Swallow			X	X	X	X	X	X	X	X	X	X				P	
Hirundinidae	*Hirundo smithii*	Wire-tailed Swallow			X	X			X					X					
Hirundinidae	*Psalidoprocne albiceps*	White-headed Saw-wing			X					X									
Hirundinidae	*Psalidoprocne pristoptera*	Black Saw-wing			X	X	X	X	X	X	X	X	X						
Hirundinidae	*Pseudhirundo griseopyga*	Grey-rumped Swallow			X						X		X						
Hirundinidae	*Ptyonoprogne fuligula*	Rock Martin			X	X		X	X		X		X	X					
Hirundinidae	*Riparia cincta*	Banded Martin		X				X					X	X					
Hirundinidae	*Riparia paludicola*	Brown-throated Martin			X	X		X	X		X		X	X					
Hirundinidae	*Riparia riparia*	Sand Martin			X			X	X									P	(X)
Indicatoridae	*Indicator indicator*	Greater Honeyguide			X	X					X		X						
Indicatoridae	*Indicator meliphilus*	Pallid Honeyguide			X	X							X						
Indicatoridae	*Indicator minor*	Lesser Honeyguide			X	X							X						
Indicatoridae	*Indicator variegatus*	Scaly-throated Honeyguide			X	X					X		X						
Indicatoridae	*Prodotiscus regulus*	Brown-backed Honeybird			X								X						
Indicatoridae	*Prodotiscus zambesiae*	Green-backed Honeybird			X	X		X					X						
Jacanidae	*Actophilornis africanus*	African Jacana			X	X		X			X								X
Jacanidae	*Microparra capensis*	Lesser Jacana		X					X					X					X
Laniidae	*Eurocephalus ruppelli*	Northern White-crowned Shrike		X								X	X						

Laniidae	*Lanius collurio*	Red-backed Shrike			X	X		X			X		X					P	
Laniidae	*Lanius excubitoroides*	Grey-backed Fiscal			X	X			X		X		X						
Laniidae	*Lanius humeralis*	Northern Fiscal			X	X	X	X			X	X	X	X					
Laniidae	*Lanius isabellinus*	Isabelline Shrike		X									X					P	
Laniidae	*Lanius minor*	Lesser Grey Shrike				X		X			X	X	X					P	
Laniidae	*Lanius phoenicuroides*	Red-tailed Shrike		X									X					P	
Laridae	*Chlidonias hybrida*	Whiskered Tern			X	X			X					X				(P)	X
Laridae	*Chlidonias leucopterus*	White-winged Tern			X	X			X									P	X
Laridae	*Chroicocephalus cirrocephalus*	Grey-headed Gull			X	X			X										X
Laridae	*Chroicocephalus genei*	Slender-billed Gull		X					X									P	X
Laridae	*Chroicocephalus ridibundus*	Black-headed Gull		X					X									P	X
Laridae	*Gelochelidon nilotica*	Gull-billed Tern			X	X			X									P	X
Laridae	*Larus fuscus*	Lesser Black-backed Gull		X					X									P	X
Leiothrichidae	*Argya rubiginosa*	Rufous Chatterer		X									X						
Leiothrichidae	*Turdoides jardineii*	Arrow-marked Babbler			X	X		X			X								
Leiothrichidae	*Turdoides sharpei*	Black-lored Babbler			X	X		X			X		X						
Locustellidae	*Bradypterus centralis*	Highland Rush Warbler			X									X					X
Locustellidae	*Bradypterus cinnamomeus*	Cinnamon Bracken Warbler			X	X	X	X		X									
Locustellidae	*Bradypterus lopezi*	Evergreen Forest Warbler			X	X	X	X		X									
Locustellidae	*Catriscus brevirostris*	Fan-tailed Grassbird		X										X					(X)
Locustellidae	*Locustella fluviatilis*	River Warbler		X					X		X							P	(X)
Locustellidae	*Luscinia megarhynchos*	Common Nightingale		X									X					P	
Locustellidae	*Melocichla mentalis*	Moustached Grass Warbler		X				X						X					(X)
Lybiidae	*Lybius leucocephalus*	White-headed Barbet			X	X		X											
Lybiidae	*Pogoniulus bilineatus*	Yellow-rumped Tinkerbird			X	X		X		X	X	X	X						
Lybiidae	*Pogoniulus leucomystax*	Moustached Tinkerbird		X			X	X		X									

Lybiidae	*Pogoniulus pusillus*	Red-fronted Tinkerbird			X	X		X	X			X	X						
Lybiidae	*Trachyphonus darnaudii*	D'Arnaud's Barbet				X						X							
Lybiidae	*Trachyphonus erythrocephalus*	Red-and-yellow Barbet				X							X						
Lybiidae	*Tricholaema diademata*	Red-fronted Barbet			X	X		X	X				X	X					
Lybiidae	*Tricholaema lacrymosa*	Spot-flanked Barbet			X								X						
Macrospheni dae	*Sylvietta brachyura*	Northern Crombec			X	X					X								
Macrospheni dae	*Sylvietta leucophrys*	White-browed Crombec			X			X		X									
Macrospheni dae	*Sylvietta whytii*	Red-faced Crombec			X	X		X	X		X		X						
Malaconotid ae	*Chlorophoneus nigrifrons*	Black-fronted Bushshrike			X	X	X	X											
Malaconotid ae	*Chlorophoneus sulfureopectus*	Orange-breasted Bushshrike			X	X		X			X	X	X						
Malaconotid ae	*Dryoscopus cubla*	Black-backed Puffback			X	X		X											
Malaconotid ae	*Dryoscopus gambensis*	Northern Puffback			X	X		X			X	X	X						
Malaconotid ae	*Laniarius funebris*	Slate-colored Boubou			X	X	X					X							
Malaconotid ae	*Laniarius major*	Tropical Boubou			X	X	X	X	X	X	X	X	X						
Malaconotid ae	*Malaconotus blanchoti*	Grey-headed Bushshrike			X	X					X		X						
Malaconotid ae	*Nilaus afer*	Brubru			X	X			X		X		X						
Malaconotid ae	*Tchagra australis*	Brown-crowned Tchagra			X	X		X					X						
Malaconotid ae	*Tchagra senegalus*	Black-crowned Tchagra			X			X					X						
Malaconotid ae	*Telophorus dohertyi*	Doherty's Bushshrike			X	X		X											
Meropidae	*Merops albicollis*	White-throated Bee-eater			X			X	X									A	
Meropidae	*Merops apiaster*	European Bee-eater			X	X		X			X		X					P	
Meropidae	*Merops bullockoides*	White-fronted Bee-eater			X	X		X	X				X						
Meropidae	*Merops nubicus*	Northern Carmine Bee-eater		X							X		X					A	
Meropidae	*Merops oreobates*	Cinnamon-chested Bee-eater			X	X	X	X	X		X	X	X						
Meropidae	*Merops persicus*	Blue-cheeked Bee-eater		X							X		X					P	
Meropidae	*Merops pusillus*	Little Bee-eater				X							X						

Meropidae	*Merops superciliosus*	Olive Bee-eater		X							X		X					A	(X)
Monarchidae	*Terpsiphone viridis*	African Paradise Flycatcher			X	X	X	X	X	X	X	X	X						
Motacillidae	*Anthus campestris*	Tawny Pipit			X	X							X					P	
Motacillidae	*Anthus cervinus*	Red-throated Pipit			X	X		X	X		X		X					P	
Motacillidae	*Anthus cinnamomeus*	African Pipit			X	X			X		X		X						
Motacillidae	*Anthus leucophrys*	Plain-backed Pipit			X	X			X		X	X	X						
Motacillidae	*Anthus similis*	Long-billed Pipit			X	X		X											
Motacillidae	*Anthus trivialis*	Tree Pipit			X	X		X			X		X					P	
Motacillidae	*Macronyx ameliae*	Rosy-throated Longclaw		X										X					(X)
Motacillidae	*Macronyx croceus*	Yellow-throated Longclaw			X	X						X	X						
Motacillidae	*Macronyx sharpei*	Sharpe's Longclaw		X										X	EN	EN	X*		
Motacillidae	*Motacilla aguimp*	African Pied Wagtail			X	X		X	X					X					(X)
Motacillidae	*Motacilla alba*	White Wagtail		X				X			X			X				P	(X)
Motacillidae	*Motacilla capensis*	Cape Wagtail			X	X		X					X	X					(X)
Motacillidae	*Motacilla cinerea*	Grey Wagtail		X			X	X		X				X				P	(X)
Motacillidae	*Motacilla clara*	Mountain Wagtail			X			X											X
Motacillidae	*Motacilla flava*	Western Yellow Wagtail			X	X		X	X		X							P	(X)
Muscicapidae	*Cercotrichas hartlaubi*	Brown-backed Scrub Robin		X									X						
Muscicapidae	*Cercotrichas leucophrys*	White-browed Scrub Robin			X	X		X					X						
Muscicapidae	*Chamaetylas poliocephala*	Brown-chested Alethe				X	X												
Muscicapidae	*Cossypha caffra*	Cape Robin-Chat			X	X	X	X	X	X		X	X	X					
Muscicapidae	*Cossypha heuglini*	White-browed Robin-Chat			X	X		X	X		X	X	X						
Muscicapidae	*Cossypha natalensis*	Red-capped Robin-Chat			X	X		X											
Muscicapidae	*Cossypha semirufa*	Rüppell's Robin-Chat			X	X	X	X		X									
Muscicapidae	*Empidornis semipartitus*	Silverbird			X								X						
Muscicapidae	*Ficedula semitorquata*	Semicollared Flycatcher		X									X			NT		P	

Muscicapidae	*Irania gutturalis*	White-throated Robin		X								X	X					P	
Muscicapidae	*Melaenornis fischeri*	White-eyed Slaty Flycatcher			X	X	X	X	X	X	X	X	X	X					
Muscicapidae	*Melaenornis microrhynchus*	African Grey Flycatcher			X	X			X		X		X						
Muscicapidae	*Melaenornis pallidus*	Pale Flycatcher			X	X					X		X						
Muscicapidae	*Melaenornis pammelaina*	Southern Black Flycatcher		X								X	X						
Muscicapidae	*Monticola rufocinereus*	Little Rock Thrush			X	X							X						
Muscicapidae	*Monticola saxatilis*	Common Rock Thrush			X	X			X		X		X					P	
Muscicapidae	*Muscicapa adusta*	African Dusky Flycatcher			X	X	X	X		X			X						
Muscicapidae	*Muscicapa caerulescens*	Ashy Flycatcher		X				X			X	X							
Muscicapidae	*Muscicapa striata*	Spotted Flycatcher			X	X			X				X					P	
Muscicapidae	*Myrmecocichla aethiops*	Anteater Chat			X	X		X	X		X		X						
Muscicapidae	*Myrmecocichla nigra*	Sooty Chat			X								X						
Muscicapidae	*Oenanthe isabellina*	Isabelline Wheatear			X								X					P	
Muscicapidae	*Oenanthe oenanthe*	Northern Wheatear			X	X			X		X		X					P	
Muscicapidae	*Oenanthe pileata*	Capped Wheatear		X									X	X				(A)	
Muscicapidae	*Oenanthe pleschanka*	Pied Wheatear			X								X					P	
Muscicapidae	*Oenanthe schalowi*	Schalow's Wheatear			X	X		X					X						
Muscicapidae	*Phoenicurus phoenicurus*	Common Redstart		X								X	X					P	
Muscicapidae	*Pogonocichla stellata*	White-starred Robin			X	X	X	X		X									
Muscicapidae	*Saxicola rubetra*	Whinchat			X			X					X					P	
Muscicapidae	*Saxicola torquatus*	African Stonechat			X	X		X						X					
Muscicapidae	*Thamnolaea cinnamomeiventris*	Mocking Cliff Chat		X									X						
Musophagidae	*Crinifer leucogaster*	White-bellied Go-away-bird		X									X						
Musophagidae	*Tauraco hartlaubi*	Hartlaub's Turaco			X	X	X			X							X		
Musophagidae	*Tauraco rossae*	Ross's Turaco				X							X						
Nectariniidae	*Anthreptes orientalis*	Eastern Violet-backed Sunbird	X		X								X						

Nectariniidae	*Chalcomitra amethystina*	Amethyst Sunbird			X	X		X	X				X						
Nectariniidae	*Chalcomitra senegalensis*	Scarlet-chested Sunbird			X	X		X	X		X	X	X						
Nectariniidae	*Cinnyris mariquensis*	Marico Sunbird		X									X						
Nectariniidae	*Cinnyris mediocris*	Eastern Double-collared Sunbird			X	X	X	X		X							X		
Nectariniidae	*Cinnyris pulchellus*	Beautiful Sunbird				X						X	X						
Nectariniidae	*Cinnyris reichenowi*	Northern Double-collared Sunbird			X	X		X	X			X	X	X					
Nectariniidae	*Cinnyris venustus*	Variable Sunbird			X	X	X	X	X		X	X	X	X					
Nectariniidae	*Cyanomitra olivacea*	Olive Sunbird			X	X	X	X											
Nectariniidae	*Cyanomitra verticalis*	Green-headed Sunbird			X	X		X					X						
Nectariniidae	*Drepanorhynchus reichenowi*	Golden-winged Sunbird			X	X	X	X		X				X					
Nectariniidae	*Hedydipna collaris*	Collared Sunbird			X	X		X			X	X	X						
Nectariniidae	*Nectarinia famosa*	Malachite Sunbird		X			X	X		X									
Nectariniidae	*Nectarinia kilimensis*	Bronzy Sunbird			X	X		X	X		X	X	X	X					
Nectariniidae	*Nectarinia tacazze*	Tacazze Sunbird			X	X	X	X											
Numididae	*Numida meleagris*	Helmeted Guineafowl			X	X							X						
Oriolidae	*Oriolus auratus*	African Golden Oriole		X								X	X					A	
Oriolidae	*Oriolus larvatus*	Black-headed Oriole			X	X		X	X		X		X						
Oriolidae	*Oriolus oriolus*	Eurasian Golden Oriole		X							X	X	X					P	
Oriolidae	*Oriolus percivali*	Mountain Oriole				X	X												
Otididae	*Ardeotis kori*	Kori Bustard	X			X							X		NT				
Otididae	*Eupodotis senegalensis*	White-bellied Bustard		X									X	X					
Otididae	*Lissotis hartlaubii*	Hartlaub's Bustard		X									X						
Otididae	*Lissotis melanogaster*	Black-bellied Bustard	X			X							X						
Otididae	*Neotis denhami*	Denham's Bustard		X									X			NT, PROT			
Pandionidae	*Pandion haliaetus*	Western Osprey			X				X				X					P	X
Paridae	*Melaniparus albiventris*	White-bellied Tit			X	X	X	X	X	X	X	X	X						

Paridae	*Melaniparus fringillinus*	Red-throated Tit		X									X				X		
Passeridae	*Gymnoris pyrgita*	Yellow-spotted Bush Sparrow			X	X							X						
Passeridae	*Passer domesticus*	House Sparrow			X	X		X					X						
Passeridae	*Passer eminibey*	Chestnut Sparrow			X			X											
Passeridae	*Passer gongonensis*	Parrot-billed Sparrow			X	X		X											
Passeridae	*Passer griseus*	Northern Grey-headed Sparrow			X	X		X					X						
Passeridae	*Passer rufocinctus*	Kenya Sparrow			X	X		X	X		X		X	X		PROT	X		
Passeridae	*Passer suahelicus*	Swahili Sparrow			X	X		X									X		
Pelecanidae	*Pelecanus onocrotalus*	Great White Pelican			X	X			X				X						X
Pelecanidae	*Pelecanus rufescens*	Pink-backed Pelican			X	X		X	X		X		X						X
Pellorneidae	*Illadopsis pyrrhoptera*	Mountain Illadopsis		X			X												
Phalacrocoracidae	*Microcarbo africanus*	Reed Cormorant			X	X		X	X					X					X
Phalacrocoracidae	*Phalacrocorax lucidus*	White-breasted Cormorant			X	X		X	X										X
Phasianidae	*Coturnix coturnix*	Common Quail				X							X	X				(P)	
Phasianidae	*Coturnix delegorguei*	Harlequin Quail		X					X					X				(A)	(X)
Phasianidae	*Dendroperdix sephaena*	Crested Francolin		X									X						
Phasianidae	*Excalfactoria (=Synoicus) adansonii*	Blue Quail		X										X				(A)	(X)
Phasianidae	*Peliperdix coqui*	Coqui Francolin			X	X							X						
Phasianidae	*Pternistis hildebrandti*	Hildebrandt's Spurfowl		X				X		X		X	X						
Phasianidae	*Pternistis leucoscepus*	Yellow-necked Spurfowl			X	X					X								
Phasianidae	*Pternistis squamatus*	Scaly Spurfowl				X	X	X											
Phasianidae	*Scleroptila psilolaema elgonensis*	Moorland Francolin		X										X		NT	X		
Phasianidae	*Scleroptila shelleyi*	Shelley's Francolin		X									X						
Phoenicopteridae	*Phoeniconaias minor*	Lesser Flamingo			X	X			X						NT	NT			X
Phoenicopteridae	*Phoenicopterus roseus*	Greater Flamingo			X	X			X										X
Phoeniculidae	*Phoeniculus bollei*	White-headed Wood Hoopoe				X	X												

Phoeniculidae	*Phoeniculus granti*	Grant's Wood Hoopoe			X						X		X						
Phoeniculidae	*Phoeniculus purpureus*	Green Wood Hoopoe			X	X		X	X		X		X						
Phoeniculidae	*Rhinopomastus cyanomelas*	Common Scimitarbill			X	X			X		X								
Phoeniculidae	*Rhinopomastus minor*	Abyssinian Scimitarbill			X								X						
Phylloscopidae	*Phylloscopus collybita*	Common Chiffchaff			X			X		X								P	
Phylloscopidae	*Phylloscopus sibilatrix*	Wood Warbler		X				X				X	X					P	
Phylloscopidae	*Phylloscopus trochilus*	Willow Warbler			X	X		X	X		X	X	X	X				P	
Phylloscopidae	*Phylloscopus umbrovirens*	Brown Woodland Warbler			X	X	X	X		X									
Picidae	*Campethera abingoni*	Golden-tailed Woodpecker			X			X											
Picidae	*Campethera nubica*	Nubian Woodpecker			X	X		X			X		X						
Picidae	*Campethera taeniolaema*	Fine-banded Woodpecker				X	X												
Picidae	*Chloropicus namaquus*	Bearded Woodpecker			X	X			X				X						
Picidae	*Dendropicos fuscescens*	Cardinal Woodpecker			X	X		X	X	X	X		X						
Picidae	*Dendropicos obsoletus*	Brown-backed Woodpecker		X							X	X	X						
Picidae	*Dendropicos spodocephalus*	Eastern Grey Woodpecker			X	X		X	X		X		X						
Picidae	*Jynx ruficollis*	Red-throated Wryneck		X				X			X								
Picidae	*Jynx torquilla*	Eurasian Wryneck		X				X			X		X					P	
Platysteiridae	*Batis molitor*	Chinspot Batis			X	X		X	X		X	X	X						
Platysteiridae	*Platysteira peltata*	Black-throated Wattle-eye			X	X		X					X						
Ploceidae	*Amblyospiza albifrons*	Thick-billed Weaver		X					X					X					
Ploceidae	*Anaplectes rubriceps*	Red-headed Weaver			X	X		X	X		X		X						
Ploceidae	*Euplectes afer*	Yellow-crowned Bishop		X					X					X					(X)
Ploceidae	*Euplectes albonotatus*	White-winged Widowbird			X	X							X						
Ploceidae	*Euplectes ardens*	Red-collared Widowbird			X			X											
Ploceidae	*Euplectes capensis*	Yellow Bishop			X			X				X	X						
Ploceidae	*Euplectes jacksoni*	Jackson's Widowbird				X								X	NT	NT	X		

Ploceidae	*Euplectes macroura*	Yellow-mantled Widowbird				X							X						
Ploceidae	*Euplectes orix*	Southern Red Bishop			X									X					(X)
Ploceidae	*Plocepasser mahali*	White-browed Sparrow-Weaver			X	X					X		X						
Ploceidae	*Ploceus baglafecht*	Baglafecht Weaver			X	X	X	X	X	X	X	X	X	X					
Ploceidae	*Ploceus cucullatus*	Village Weaver			X	X		X	X		X		X						
Ploceidae	*Ploceus insignis*	Brown-capped Weaver			X	X	X	X											
Ploceidae	*Ploceus intermedius*	Lesser Masked Weaver			X	X		X			X		X						
Ploceidae	*Ploceus jacksoni*	Golden-backed Weaver			X			X											
Ploceidae	*Ploceus melanogaster*	Black-billed Weaver			X	X		X					X						
Ploceidae	*Ploceus nigricollis*	Black-necked Weaver			X	X		X	X										
Ploceidae	*Ploceus ocularis*	Spectacled Weaver			X	X	X	X	X	X	X		X						
Ploceidae	*Ploceus rubiginosus*	Chestnut Weaver			X	X		X											
Ploceidae	*Ploceus spekei*	Speke's Weaver			X	X			X		X		X	X					
Ploceidae	*Ploceus vitellinus*	Vitelline Masked Weaver			X	X					X	X	X						
Ploceidae	*Ploceus xanthops*	Holub's Golden Weaver			X		X												
Ploceidae	*Pseudonigrita arnaudi*	Grey-capped Social Weaver		X									X						
Ploceidae	*Quelea cardinalis*	Cardinal Quelea		X					X					X					
Ploceidae	*Quelea quelea*	Red-billed Quelea			X	X		X						X				(A)	
Ploceidae	*Sporopipes frontalis*	Speckle-fronted Weaver		X									X						
Podicipedidae	*Podiceps cristatus*	Great Crested Grebe		X					X							PROT			X
Podicipedidae	*Podiceps nigricollis*	Black-necked Grebe				X			X										X
Podicipedidae	*Tachybaptus ruficollis*	Little Grebe			X	X		X						X					X
Psittacidae	*Poicephalus meyeri*	Meyer's Parrot			X								X						
Psittaculidae	*Agapornis fischeri*	Fischer's Lovebird			X	X		X	X		X		X		(NT only in Tanzania)				
Psittaculidae	*Agapornis personatus*	Yellow-collared Lovebird			X	X					X		X						
Pycnonotidae	*Arizelocichla kikuyuensis*	Olive-breasted Greenbul			X	X	X	X		X									

Pycnonotidae	*Eurillas latirostris*	Yellow-whiskered Greenbul			X	X	X	X		X			X						
Pycnonotidae	*Phyllastrephus placidus*	Placid Greenbul			X	X	X	X											
Pycnonotidae	*Phyllastrephus strepitans*	Northern Brownbul		X							X		X						
Pycnonotidae	*Pycnonotus tricolor*	Dark-capped Bulbul			X	X	X	X	X	X	X	X	X	X					
Pycnonotidae	*Stelgidillas gracilirostris*	Slender-billed Greenbul			X	X	X	X											
Rallidae	*Aenigmatolimnas marginalis*	Striped Crake			X									X				A	X
Rallidae	*Crecopsis egregia*	African Crake			X			X										A	X
Rallidae	*Crex crex*	Corn Crake		X					X					X		NT		P	(X)
Rallidae	*Fulica cristata*	Red-knobbed Coot			X			X											X
Rallidae	*Gallinula chloropus*	Common Moorhen			X	X		X						X					X
Rallidae	*Paragallinula angulata*	Lesser Moorhen		X					X					X				(A)	X
Rallidae	*Porphyrio alleni*	Allen's Gallinule		X					X					X				(A)	X
Rallidae	*Porphyrio madagascariensis*	African Swamphen			X			X											X
Rallidae	*Porzana porzana*	Spotted Crake		X					X					X				P	X
Rallidae	*Rallus caerulescens*	African Rail			X	X			X		X			X					X
Rallidae	*Zapornia flavirostra*	Black Crake			X	X		X	X		X			X					X
Rallidae	*Zapornia pusilla*	Baillon's Crake				X								X		PROT		(A)	X
Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt			X	X		X	X										X
Recurvirostridae	*Recurvirostra avosetta*	Pied Avocet			X	X		X	X										X
Remizidae	*Anthoscopus caroli*	Grey Penduline Tit		X								X	X						
Rostratulidae	*Rostratula benghalensis*	Greater Painted-snipe		X					X									(A)	X
Sagittariidae	*Sagittarius serpentarius*	Secretarybird			X	X							X		EN	PROT			
Sarothruridae	*Sarothrura affinis*	Striped Flufftail		X										X					
Sarothruridae	*Sarothrura boehmi*	Streaky-breasted Flufftail		X					X					X				A	X
Sarothruridae	*Sarothrura elegans*	Buff-spotted Flufftail		X			X	X		X									
Sarothruridae	*Sarothrura rufa*	Red-chested Flufftail		X					X					X					X

Scolopacidae	*Actitis hypoleucos*	Common Sandpiper			X	X			X		X							P	X
Scolopacidae	*Arenaria interpres*	Ruddy Turnstone		X					X									P	X
Scolopacidae	*Calidris alba*	Sanderling			X				X									P	X
Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper			X	X			X						NT			P	X
Scolopacidae	*Calidris minuta*	Little Stint			X	X			X									P	X
Scolopacidae	*Calidris pugnax*	Ruff			X	X			X		X							P	X
Scolopacidae	*Calidris temminckii*	Temminck's Stint		X					X									P	X
Scolopacidae	*Gallinago gallinago*	Common Snipe			X						X							P	X
Scolopacidae	*Gallinago media*	Great Snipe		X										X	NT	NT		P	X
Scolopacidae	*Gallinago nigripennis*	African Snipe			X	X								X					X
Scolopacidae	*Limosa limosa*	Black-tailed Godwit		X					X						NT	NT		P	X
Scolopacidae	*Lymnocryptes minimus*	Jack Snipe		X										X				P	X
Scolopacidae	*Numenius arquata*	Eurasian Curlew		X					X						NT	NT		P	X
Scolopacidae	*Numenius phaeopus*	Eurasian Whimbrel		X					X									P	X
Scolopacidae	*Tringa erythropus*	Spotted Redshank				X			X									P	X
Scolopacidae	*Tringa glareola*	Wood Sandpiper			X	X		X	X		X			X				P	X
Scolopacidae	*Tringa nebularia*	Common Greenshank			X	X			X									P	X
Scolopacidae	*Tringa ochropus*	Green Sandpiper			X	X		X	X		X	X						P	X
Scolopacidae	*Tringa stagnatilis*	Marsh Sandpiper			X	X			X		X							P	X
Scolopacidae	*Tringa totanus*	Common Redshank		X					X									P	X
Scopidae	*Scopus umbretta*	Hamerkop			X	X		X			X	X	X	X					X
Stenostiridae	*Elminia albonotata*	White-tailed Crested Flycatcher				X	X												
Stenostiridae	*Elminia longicauda*	African Blue Flycatcher			X	X		X					X						
Strigidae	*Asio capensis*	Marsh Owl		X										X					(X)
Strigidae	*Bubo africanus*	Spotted Eagle-Owl		X				X			X	X	X						
Strigidae	*Bubo capensis*	Cape Eagle-Owl		X				X								PROT			

Strigidae	*Bubo lacteus*	Verreaux's Eagle-Owl		X							X		X						
Strigidae	*Glaucidium perlatum*	Pearl-spotted Owlet		X									X						
Strigidae	*Otus scops*	Eurasian Scops Owl		X								X	X					P	
Strigidae	*Otus senegalensis*	African Scops Owl		X									X						
Strigidae	*Strix woodfordii*	African Wood Owl			X			X											
Sturnidae	*Cinnyricinclus leucogaster*	Violet-backed Starling			X	X							X					A	
Sturnidae	*Creatophora cinerea*	Wattled Starling			X	X					X							(A)	
Sturnidae	*Lamprotornis chalybaeus*	Greater Blue-eared Starling			X	X		X			X		X						
Sturnidae	*Lamprotornis hildebrandti*	Hildebrandt's Starling			X								X				X		
Sturnidae	*Lamprotornis purpuroptera*	Rüppell's Starling			X	X			X		X		X						
Sturnidae	*Lamprotornis superbus*	Superb Starling			X	X		X			X	X	X	X					
Sturnidae	*Onychognathus morio*	Red-winged Starling				X		X											
Sturnidae	*Onychognathus tenuirostris*	Slender-billed Starling			X			X											
Sturnidae	*Onychognathus walleri*	Waller's Starling				X				X									
Sturnidae	*Poeoptera femoralis*	Abbott's Starling		X			X			X					VU	VU	X		
Sturnidae	*Poeoptera sharpii*	Sharpe's Starling				X				X									
Sylviidae	*Curruca communis*	Common Whitethroat		X							X		X					P	
Sylviidae	*Curruca lugens*	Brown Parisoma			X	X		X			X	X	X						
Sylviidae	*Sylvia abyssinica*	African Hill Babbler			X	X	X	X		X									
Sylviidae	*Sylvia atricapilla*	Eurasian Blackcap			X		X	X					X					P	
Sylviidae	*Sylvia borin*	Garden Warbler			X			X										P	
Threskiornithidae	*Bostrychia hagedash*	Hadada Ibis			X	X		X		X	X	X	X	X					(X)
Threskiornithidae	*Platalea alba*	African Spoonbill			X	X		X	X				X						X
Threskiornithidae	*Plegadis falcinellus*	Glossy Ibis			X	X		X	X		X			X					X
Threskiornithidae	*Threskiornis aethiopicus*	African Sacred Ibis			X	X		X	X		X			X					X
Trogonidae	*Apaloderma narina*	Narina Trogon			X			X											

Trogonidae	*Apaloderma vittatum*	Bar-tailed Trogon				X	X												
Turdidae	*Geokichla gurneyi*	Orange Ground Thrush				X	X												
Turdidae	*Geokichla piaggiae*	Abyssinian Ground Thrush			X	X		X											
Turdidae	*Turdus abyssinicus*	Abyssinian Thrush			X	X	X	X		X			X						
Turdidae	*Turdus pelios*	African Thrush			X			X			X		X						
Turnicidae	*Turnix sylvaticus*	Common Buttonquail		X									X						
Tytonidae	*Tyto alba*	Western Barn Owl			X	X		X					X						
Tytonidae	*Tyto capensis*	African Grass Owl		X										X					(X)
Upupidae	*Upupa africana*	African Hoopoe			X	X					X		X						
Upupidae	*Upupa epops*	Eurasian Hoopoe			X	X		X			X							P	
Vangidae	*Prionops plumatus*	White-crested Helmetshrike			X	X							X						
Vangidae	*Prionops poliolophus*	Grey-crested Helmetshrike				X							X		NT	NT	X		
Viduidae	*Anomalospiza imberbis*	Cuckoo-finch		X										X					
Viduidae	*Vidua chalybeata*	Village Indigobird				X							X						
Viduidae	*Vidua fischeri*	Straw-tailed Whydah				X							X						
Viduidae	*Vidua macroura*	Pin-tailed Whydah			X	X		X					X	X					
Viduidae	*Vidua paradisaea*	Long-tailed Paradise Whydah		X									X						
Viduidae	*Vidua purpurascens*	Purple Indigobird		X									X						
Zosteropidae	*Zosterops flavilateralis*	Pale White-eye				X		X											
Zosteropidae	*Zosterops kikuyuensis*	Kikuyu White-eye			X	X	X	X	X	X	X	X	X				X*		
Zosteropidae	*Zosterops senegalensis*	Northern Yellow White-eye			X	X		X				X	X						

10. APPENDIX 2

Examples of "typical" natural broad-scale habitat units on the survey area: (a - d) Afromontane Undifferentiated Forest (AUF), (e - h) Afromontane Rainforest (AfR), (i - l) Afromontane Bamboo (AfmB), (m - p) Upper *Acacia* Wooded Grassland (UAWG), (q - v) Evergreen and semi-evergreen Bushland and Thicket (ESEBT), (w - z) Edaphic Wooded Grassland (EWG), (aa - dd) Riparian Wooded Vegetation (RWV) and (ee - jj) Halophytic Vegetation (HalV).


a)


b)


c)


d)


e)


f)


g)


h)


i)


j)


k)


l)

m)

n)

o)

p)

q)

r)

s)

t)

u)

v)

w)

x)


y)


z)


aa)


bb)


cc)


dd)

ee)

ff)

gg)

hh)

ii)

jj)

11. APPENDIX 3

Examples illustrating the habitat structure of special zones of natural habitat on the survey area : (a - d) Kinale Forest, (e - h) Thika-Mango flyover grasslands, (i - l) Kenya Wildlife Service sanctuary, (m - p) Marula Estates and the Soysambu Conservancy road reserves, (q - t) Koibatek Forest patch, (u - x) Molo forest-plantation zone, (y - bb) Manguo Pond, (cc - ff) Elmenteita dry ridge habitat and (gg - jj) Escarpment forest.

a)

b)

c)

d)

e)

f)

g)

h)

i)

j)


k)


l)


m)


n)


o)


p)

q)

r)

s)

t)

u)

v)


w)


x)


y)


z)


aa)


bb)


cc)


dd)


ee)


ff)


gg)


hh)

ii)

jj)

12. APPENDIX 4

A list of expected and observed Biome-restricted species on the survey area. AfR - Afromontane Rainforest, AUF - Afromontane Undifferentiated Forest, AfmB - Afromontane Bamboo, HalV - Halophytic Vegetation, UAWG - Upper *Acacia* Wooded Grassland, ESEBT- Evergreen and semi-evergreen bushland and thicket, RWV - Riparian Wooded Vegetation and EWG - Edaphic Wooded Grassland.

Family	Species	Common Name	Expected (not observed)	Field Campaign		Habitats where the species was surveyed/expected								Biome		
				Feb-21	Apr-21	AfR	AUF	HalV	AfmB	RWV	UAWG	ESEBT	EWG	Afrotropical Highlands	Somali-Masai	Lake Victoria Basin
Accipitridae	*Buteo oreophilus*	Mountain Buzzard		X	X	X	X		X					X		
Acrocephalidae	*Iduna similis*	Mountain Yellow Warbler		X	X	X	X		X					X		
Alaudidae	*Alaudala athensis*	Athi Short-toed Lark	X									X			X	
Apodidae	*Apus niansae*	Nyanza Swift		X	X		X	X	X	X		X		X		
Apodidae	*Schoutedenapus myoptilus*	Scarce Swift		X	X		X					X		X		
Campephagidae	*Ceblepyris caesius*	Grey Cuckooshrike		X	X	X	X		X					X		
Caprimulgidae	*Caprimulgus fraenatus*	Sombre Nightjar		X			X								X	
Caprimulgidae	*Caprimulgus poliocephalus*	Montane Nightjar		X	X		X							X		
Cisticolidae	*Apalis porphyrolaema*	Chestnut-throated Apalis		X	X	X	X		X					X		
Cisticolidae	*Cisticola hunteri*	Hunter's Cisticola		X	X	X	X		X			X	X	X		
Cisticolidae	*Oreolais pulcher*	Black-collared Apalis		X	X	X	X					X		X		
Emberizidae	*Emberiza poliopleura*	Somali Bunting			X							X			X	
Estrildidae	*Cryptospiza salvadorii*	Abyssinian Crimsonwing		X	X	X	X		X					X		
Estrildidae	*Granatina ianthinogaster*	Purple Grenadier		X	X		X	X		X		X			X	
Estrildidae	*Spermestes griseicapilla*	Grey-headed Silverbill			X							X			X	
Fringillidae	*Crithagra buchanani*	Southern Grosbeak-Canary		X	X			X		X					X	
Fringillidae	*Crithagra burtoni*	Thick-billed Seedeater		X	X	X	X	X						X		
Fringillidae	*Crithagra citrinelloides*	African Citril		X	X	X	X	X	X	X	X	X	X	X		

Fringillidae	*Crithagra dorsostriata*	White-bellied Canary		X	X							X			X	
Fringillidae	*Crithagra striolata*	Streaky Seedeater		X	X	X	X	X	X		X	X	X	X		
Leiothrichidae	*Argya rubiginosa*	Rufous Chatterer	X									X			X	
Leiothrichidae	*Turdoides sharpei*	Black-lored Babbler		X	X		X			X		X				X
Locustellidae	*Bradypterus cinnamomeus*	Cinnamon Bracken Warbler		X	X	X	X		X					X		
Lybiidae	*Pogoniulus leucomystax*	Moustached Tinkerbird	X			X	X		X					X		
Lybiidae	*Trachyphonus darnaudii*	D'Arnaud's Barbet			X						X				X	
Lybiidae	*Trachyphonus erythrocephalus*	Red-and-yellow Barbet			X							X			X	
Macrosphenidae	*Sylvietta leucophrys*	White-browed Crombec		X			X		X					X		
Malaconotidae	*Telophorus dohertyi*	Doherty's Bushshrike		X	X		X							X		
Meropidae	*Merops oreobates*	Cinnamon-chested Bee-eater		X	X	X	X	X		X	X	X		X		
Motacillidae	*Macronyx sharpei*	Sharpe's Longclaw	X										X	X		
Muscicapidae	*Cossypha semirufa*	Rüppell's Robin-Chat		X	X	X	X		X					X		
Muscicapidae	*Melaenornis fischeri*	White-eyed Slaty Flycatcher		X	X	X	X	X	X	X	X	X	X	X		
Muscicapidae	*Melaenornis microrhynchus*	African Grey Flycatcher		X	X			X		X		X			X	
Muscicapidae	*Monticola rufocinereus*	Little Rock Thrush		X	X							X		X		
Muscicapidae	*Pogonocichla stellata*	White-starred Robin		X	X	X	X		X					X		
Musophagidae	*Crinifer leucogaster*	White-bellied Go-away-bird	X									X			X	
Musophagidae	*Tauraco hartlaubi*	Hartlaub's Turaco		X	X	X			X					X		
Nectariniidae	*Anthreptes orientalis*	Eastern Violet-backed Sunbird		X								X			X	
Nectariniidae	*Cinnyris mediocris*	Eastern Double-collared Sunbird		X	X	X	X		X					X		
Nectariniidae	*Cinnyris reichenowi*	Northern Double-collared Sunbird		X	X		X	X			X	X	X	X		
Nectariniidae	*Drepanorhynchus reichenowi*	Golden-winged Sunbird		X	X	X	X		X				X	X		
Nectariniidae	*Nectarinia kilimensis*	Bronzy Sunbird		X	X		X	X		X	X	X	X	X		
Nectariniidae	*Nectarinia tacazze*	Tacazze Sunbird		X	X	X	X							X		
Oriolidae	*Oriolus percivali*	Mountain Oriole			X	X								X		

Paridae	*Melaniparus fringillinus*	Red-throated Tit	X									X			X	
Pellorneidae	*Illadopsis pyrrhoptera*	Mountain Illadopsis	X			X								X		
Phasianidae	*Pternistis leucoscepus*	Yellow-necked Spurfowl		X	X					X					X	
Phasianidae	*Scleroptila psilolaema elgonensis*	Moorland Francolin	X										X	X		
Phoeniculidae	*Rhinopomastus minor*	Abyssinian Scimitarbill		X								X			X	
Phylloscopidae	*Phylloscopus umbrovirens*	Brown Woodland Warbler		X	X	X	X		X					X		
Picidae	*Campethera taeniolaema*	Fine-banded Woodpecker			X	X								X		
Ploceidae	*Euplectes jacksoni*	Jackson's Widowbird			X								X	X		
Ploceidae	*Ploceus baglafecht*	Baglafecht Weaver		X	X	X	X	X	X	X	X	X	X	X		
Ploceidae	*Ploceus insignis*	Brown-capped Weaver		X	X	X	X							X		
Ploceidae	*Ploceus melanogaster*	Black-billed Weaver		X	X		X					X		X		
Ploceidae	*Ploceus spekei*	Speke's Weaver		X	X			X		X		X	X		X	
Sarothruridae	*Sarothrura affinis*	Striped Flufftail	X										X	X		
Stenostiridae	*Elminia albonotata*	White-tailed Crested Flycatcher			X	X								X		
Sturnidae	*Lamprotornis hildebrandti*	Hildebrandt's Starling		X								X			X	
Sturnidae	*Onychognathus tenuirostris*	Slender-billed Starling		X			X							X		
Sturnidae	*Onychognathus walleri*	Waller's Starling			X				X					X		
Sturnidae	*Poeoptera femoralis*	Abbott's Starling	X			X			X					X		
Sturnidae	*Poeoptera sharpii*	Sharpe's Starling			X				X					X		
Sylviidae	*Curruca lugens*	Brown Parisoma		X	X		X			X	X	X		X		
Sylviidae	*Sylvia abyssinica*	African Hill Babbler		X	X	X	X		X					X		
Trogonidae	*Apaloderma vittatum*	Bar-tailed Trogon			X	X								X		
Turdidae	*Geokichla gurneyi*	Orange Ground Thrush			X	X								X		
Turdidae	*Geokichla piaggiae*	Abyssinian Ground Thrush		X	X		X							X		
Vangidae	*Prionops poliolophus*	Grey-crested Helmetshrike			X							X			X	
Viduidae	*Vidua fischeri*	Straw-tailed Whydah			X							X			X	

Zosteropidae	*Zosterops flavilateralis*	Pale White-eye			X		X								X	
Zosteropidae	*Zosterops kikuyuensis*	Kikuyu White-eye		X	X	X	X	X	X	X	X	X		X		
														50	21	
		72														
		10														
		62														

13. APPENDIX 5

A collage of bird species photographed on the survey area during the survey campaigns of February and April 2021.

a) Schalow's Wheatear (*Oenanthe schalowi*) - male

b) Schalow's Wheatear (*Oenanthe schalowi*) - female

c) Abysinninan Ground-Trush (*Geokichla piaggiae*) - an Afrotropical Highlands Biome species

d) Abysinnian Thrush (*Turdus abyssinicus*)

e) Baglafecht Weaver (*Ploceus baglafecht*), male - an Afrotropical Highlands Biome species

f) Baglafecht Weaver (*Ploceus baglafecht*), female - an Afrotropical Highlands Biome species

g) Thick-billed Seedeater (*Crithagra burtoni*) - an Afrotropical Highlands species

h) Abysinnian Crimsonwing (*Cryptospiza salvadorii*) - an Afrotropical Highlands species

i) Yellow-spotted Bush-sparrow (*Gymnoris pyrgita*)

j) Kenya Sparrow (*Passer rufocinctus*) - endemic to East Africa

k) Streaky Seedeater (*Crithagra striolata*) - an Afrotropical Highlands species

l) Yellow Bishop (*Euplectes capensis*) - female


m) Fischer's Lovebird (*Agapornis fischeri*)


n) White-browed Robin-chat (*Cossypha heuglini*)


o) White-headed Barbet (*Lybius leucocephalus*)


p) Rüppell's Starling (*Lamprotornis purpuroptera*)


q) Superb Starling (*Lamprotornis superbus*)


r) Grey-capped Warbler (*Eminia lepida*)

s) Olive-breasted Mountain Greenbul (*Arizelocichla kikuyuensis*)

t) African Hill-babbler (*Sylvia [=Pseudoalcippe] abyssinica*) an Afrotropical Highlands Biome species

u) Pectoral-patch Cisticola (*Cisticola brunnescens*)

v) Red-capped Lark (*Calandrella cinerea*)

w) Black-troated Wattle-eye (*Platysteira peltata*) - female

y) Cape Teal (*Anas smithii*)

x) Golden-winged Sunbird (*Drepanorhynchus reichenowi*) - an Afrotropical Highlands Biome species

z) Grey-headed Gull (*Chroicocephalus cirrocephalus*)

aa) Little Stint (*Calidris minuta*) - foreground, Kittlitz's Plover (*Charadrius pecuarius*) - middle & Kentish Plover (*C. alexandrinus*) - background

bb) Black-winged Lapwing (*Vanellus melanopterus*)

cc) Little Stint (*Calidris minuta*) - a Palearctic migrant

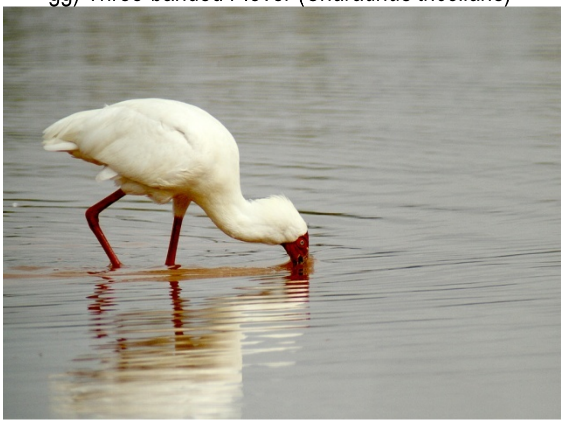
dd) Marabou Sotrk (*Leptoptilos crumenifer*)

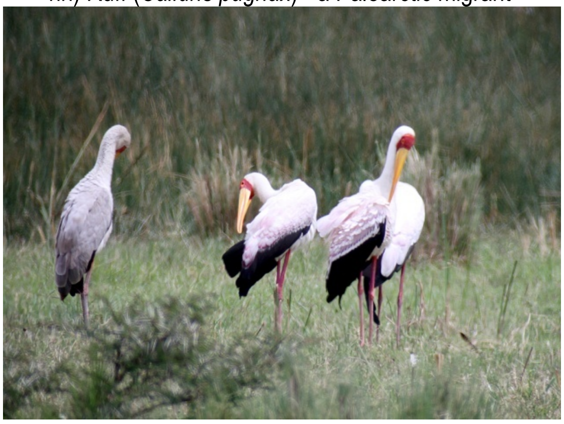
ee) Great White Pelican (*Pelecanus onocrotalus*) - background & Pink-backed Pelican (*P. rufescens*) - foreground

ff) Common Ringed Plover (*Charadrius hiaticula*) - a Palearctic migrant


gg) Three-banded Plover (*Charadrius tricollaris*)


hh) Ruff (*Calidris pugnax*) - a Palearctic migrant


ii) African Spoonbill (*Platalea alba*)


jj) Yellow-billed Stork (*Mycteria alba*)

APPENDIX

6-17 *BIODIVERSITY BASELINE INVESTIGATION – HERPETOLOGY*

Nairobi-Nakuru-Mau Summit Highway Project
Biodiversity baseline studies for the ESIA
Republic of Kenya

BIODIVERSITY BASELINE INVESTIGATION
HERPETOLOGY
FINAL REPORT

Compiled by:
Marius Burger, *Pri.Sci.Nat.*
Ryan van Huyssteen

July 2021

Document history

Version	Reviewed by	Requests noted
Draft V1	Jerome Gaugris, *Pri. Sci. Nat.*	
Draft V2	WSP - Maya Brennan Jacot	
FINAL version	Marius Burger, *Pri.Sci.Nat.* Phoebe Mottram, *Cand.Sci.Nat* Jerome Gaugris, *Pri.Sci.Nat.*	

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BIODIVERSITY BASELINE INVESTIGATION
HERPETOLOGY

1. CONTEXT

WSP Canada has been commissioned by Rift Valley Highway Limited (RVHL) to complete the Environmental and Social Impact Assessment (ESIA) for the Nairobi-Nakuru-Mau Summit Highway Project. The ESIA is undertaken in order to anticipate and identify adverse environmental and social risks and develop robust mitigation measures through the application of mitigation hierarchy. As part of the WSP Canada consortium in the proposal made to RVHL, Flora Fauna & Man Ecological Services Ltd (FFMES) has been tasked to undertake the biodiversity surveys along the proposed road alignment. A first round of work, covering the dry season was undertaken in February 2021, from 17 to 26 February (10 days of field work). Another round of work, covering the wet season, was undertaken from 13 to 25 April 2021 (12 days of field work). The work was undertaken by a multidisciplinary team of experts spanning the following disciplines:

- Vegetation, including woody biomass;
- Mammals (including small terrestrial mammals);
- Avifauna;
- Herpetofauna (Reptiles & Amphibians);
- Freshwater ecology.

The present document provides an outline of the work undertaken with respect to the following discipline:

- Herpetofauna (Reptiles & Amphibians).

This work was undertaken by the following team members:

- Marius Burger (MB)
  - National Diploma Nature Conservation.
  - Registered with SACNASP as a Professional Natural Scientist for the fields of Ecological Science and Zoological Science (Reg. no. 130600).
  - Collectively about 35 years of experience in nature conservation (11 years), and environmental impact assessment and biodiversity projects (24 years).
  - Published 44 scientific peer-reviewed articles, 75 semi-scientific and popular articles, and authored/edited three books and 35 chapters/accounts in books.
  - Previous experience in Kenya and other East African countries are mostly limited to services related to eco-tourism and wildlife television productions (about five trips), and six trips to Ethiopia for environmental impact consultancy projects.
- Ryan van Huyssteen (RVH)
  - BA Honours (Philosophy), BA (Journalism)
  - Eight years of experience in faunal surveys and biodiversity projects.
  - Published 13 peer-reviewed articles.
- Beryl A. Bwong (BAB)
  - PhD in Environmental Sciences.
  - Life-long Kenyan resident with 20 years of experience in the study of amphibians and reptiles in Kenya. Employed as a herpetologist at Nairobi National Museum (NNM).
  - Published 15 peer-reviewed scientific articles, 17 unpublished and technical field reports, and co-authored one book.

2. STUDY AREA

2.1. Location and general description

The project is located south of the Equator in the south-central part of Kenya. The project covers approximately 175 km of road from the junction between the Old Naivasha and Limuru Roads near Nairobi in the south to the Mau summit near the A104 highway and A8 road junction in the north. The project also involves the survey of habitat units along the proposed strengthening of the A8 South Highway (Old Naivasha Road). This road, of approximately 57.4 km in length and is located between the junction of the Old Naivasha Road with Limuru Road in the south and the Naivasha town in the north (**Error! Reference source not found.**).

The study area corresponds to the Project's Biodiversity Local Assessment Area, which includes a 2 km buffer on either side of the roads. It is situated within the southern Rift Valley Province while also traversing near a number of protected areas and conservancies such as the Gatamaiyo Forest Nature Reserve (part of the Kinale forest block), the Longonot, Lake Naivasha and Lake Nakuru National Parks, and conservancies such as Marula Estates, the Kigio Wildlife Conservancy and the Soysambu Conservancy at Lake Elmenteita. The Regional Assessment Area incorporates tremendous topographical diversity which includes the Great Rift Valley and its associated escarpments and volcanoes. It also incorporates a chain of endorheic lakes (Lakes Naivasha, Elmenteita and Nakuru) located within several basins of internal drainage in the Rift Valley. The northern and southern parts overlap with the central highlands and encompass a number of highland moist forest patches and upland grassland.

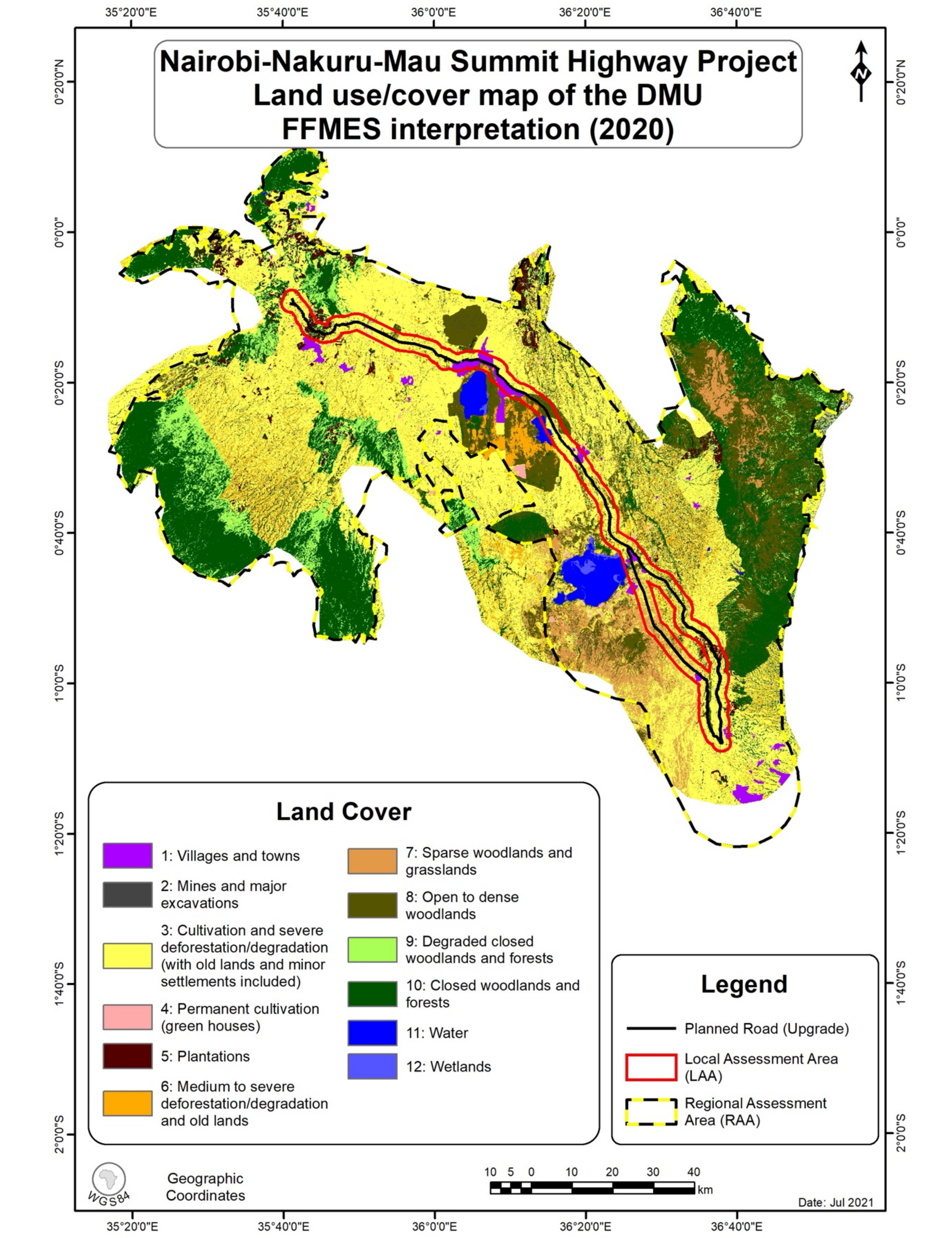


Figure 1: Location of the Nairobi-Nakuru-Mau Summit Highway Project in Kenya, including the Local Assessment Area and Regional Assessment Area. The figure highlights the land cover types defined in the Land Use and Land Use Change Analysis conducted for this project by FFMES.

2.2. Vegetation types

The study area is characterised by eight broad-scale habitat classes according to the VECEA[1] potential natural vegetation map for Eastern Africa (van Breugel et al, 2015) located within a 2 km buffer area on either side of the road. These units differ from each other in floristic composition, floristic structure and topography (Figure 2 and Table 1). Most of these floristic associations and habitats are characteristic of the Afrotropical Highlands Biome. However, many of the units are invariably associated with anthropogenic activities, which range from settlements and urban areas to cultivation and pastoralism, thereby rendering large parts of these habitat units as degraded and of secondary succession (e.g. perturbed), while certain parts show a high prevalence of alien plant infestation. Some of the habitat types are classified as azonal habitat, which refer mainly to areas of lentic (stationary or relatively still) surface water (e.g. artificial dams, ponds or pans). The broad-scale habitat types corresponding to the study area that was surveyed during the herpetofaunal investigation are as follow:

- Afromontane Undifferentiated Forest (AUF)
- Afromontane Rainforest (AfR)
- Afromontane Bamboo (AfmB)
- Upper Acacia Wooded Grassland (UAWG)
- Evergreen and Semi evergreen Bushland and Thicket (ESEBT)
- Edaphic wooded grassland (EWG)
- Riverine wooded vegetation (RWV)
- Halophytic vegetation (HalV)

[1] Vegetation and Climate change in East Africa project.

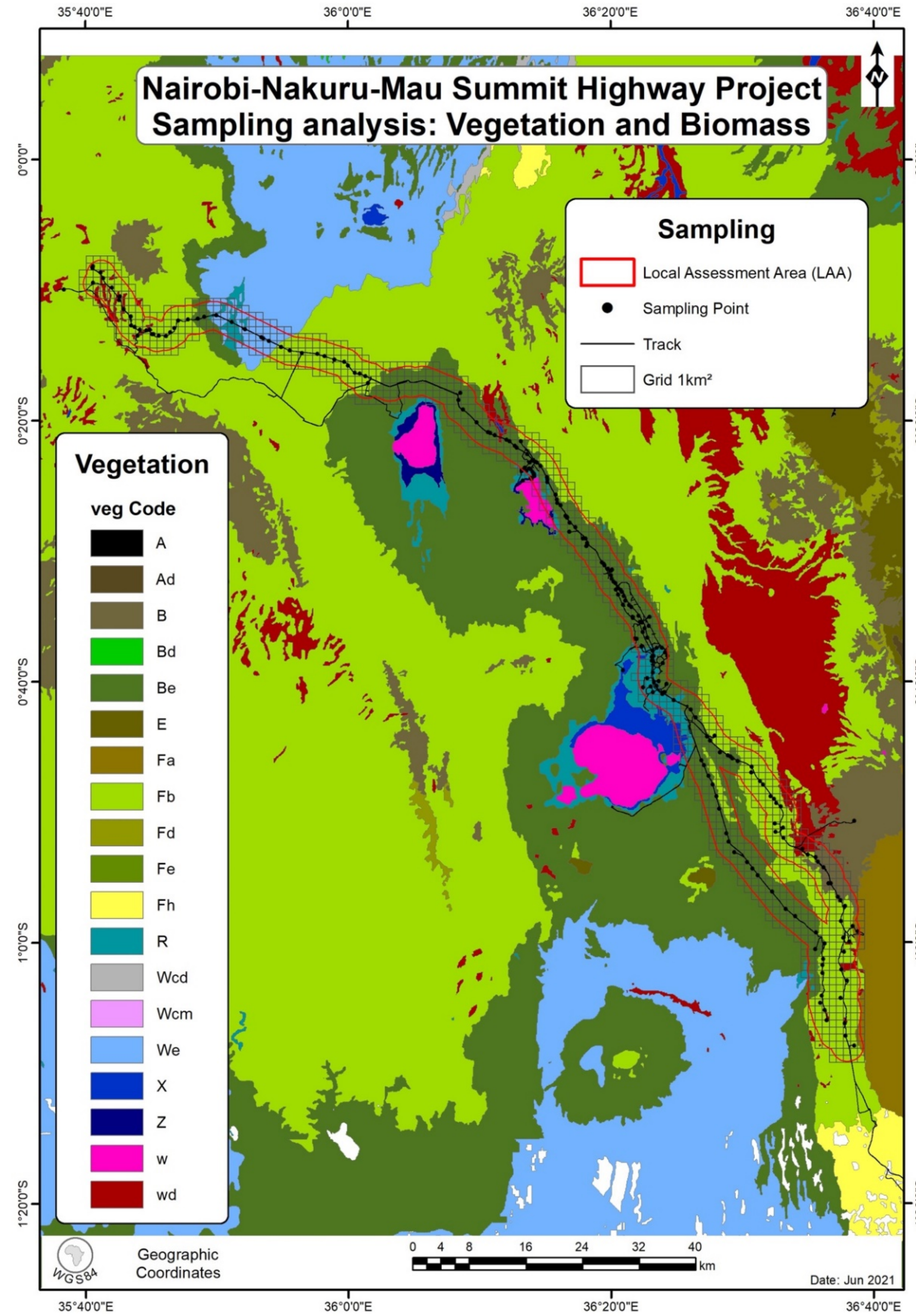


Figure 2: The spatial location of the broad-scale habitat types on the Local Assessment Area (located within a 2 km survey/buffer area of on either side of the road). The habitat classification follows the VECEA potential natural vegetation map for Eastern Africa (van Breugel et al. 2015).

2.3. Other habitat types

The A8 road traverses predominantly through Modified Habitat (see Bennun et al. 2018 and the Land Use and Land Use Change Analysis report), although some sections of the study area along the road upgrade may cause the loss of small areas of Natural Habitat that are of interest. These areas (so-called special zones) include mainly untransformed or semi-transformed habitat with compositions of unique biodiversity life-forms, which inter alia may include threatened, endemic and/ or biome-restricted bird species. These special zones are summarised in Table 1 and Figure 3.

Table 1: The special zones of Natural Habitat corresponding to the study area that was surveyed during the herpetofaunal investigation.

Special Zone	Description
1. Kinale Forest	Small patches of indigenous forest and scrub located along the road alignment, although large tracts of untransformed forest occur in the Gatamaiyo Forest Nature Reserve east of the road alignment These patches, including the regenerating understory of indigenous shrubs and trees under the plantations, are potentially important in maintaining connectivity between indigenous forest on the escarpment and in the Kikuyu Escarpment Forest to the north-east.
2. Thika-Mango flyover grasslands	This zone includes small patches of degraded and fragmented highland grassland between Kinale Forest and the Thika-Mango flyover, and provides a potential dispersal corridor for bird and other animal species to the Kinale forest.
3. Kenya Wildlife Service sanctuary	The Kenya Wildlife Service sanctuary contains large stands of mature Leleswhe (*Tarchonanthus*) and *Acacia*-dominated shrubland in an otherwise urban landscape (located in Naivasha).
4. Marula Estates road reserve	This zone lies within the road reserve where it borders the Marula Estates. It includes mature and good examples of *Acacia xanthophloea* woodland.
5. Soysambu road reserve	This zone lies within the road reserve adjacent to the Soysambu Conservancies, between Naivasha and Nakuru. It contains open dry grassland and mature examples of Leleswhe and *Acacia* habitats.
6. Koibatek Forest Patch	This zone includes a small section of indigenous forest where the road crosses the Koibatek Forest from Sachangwan to Kibunja trading center.
7. Molo forest-plantation zone	This zone includes a mosaic of indigenous forest patches within plantations. It is located immediately to the north of the Koibatek forest patch.
8. Manguo Pond	This is a large seasonally inundated wetland depression north-east of the road just beyond the Limuru Flyover
9. Elmenteita dry ridge habitat	This zone includes deep valleys and ridges near Lake Elmenteita. It differs from the dominant vegetation in the area since it is covered in arid shrubland with a high prevalence of sclerophyllous and succulent plant species (including *Euphorbia* species).
8. Escarpment forest	This unit is located along the A8 South road on the escarpment west of the main A8 highway. It consists of large section of contiguous indigenous forest. It forms a corridor via the Kinale forest zone with the Kikuyu Escarpment Forest.

3. METHODS

3.1. Field surveys 1 and 2

The first field survey was conducted during 17 to 26 February (10 days of field work), a period representative of a dry season assessment. This survey was conducted by one herpetologist (MB). The primary aims of this survey were for the herpetologist to become familiar with the habitat diversity within the study area, and to actively search for reptile and amphibian species at predetermined sampling points. The second field survey was conducted during 13 to 25 April (12 days of field work), a period representative of a wet season assessment. This survey was conducted by a team of three herpetologist (MB, RVH and BAB). The second survey aimed to expand on the data obtained during the first survey, i.e. to meet the survey targets of the sampling sites and to improve on the species observations data set.

3.1.1. Active searching at sampling points

Prior to conducting the first field surveys, a total of 442 sampling points were pre-selected by FFMES as a range of points of interest from which experts could select the places that they would prefer to investigate. The points were selected using a "multistage stratified semi-random sampling" (MSSRS) approach applied to the sampling grid composed of 980 grid cells of 1 km² each. The sampling grid was defined by the 2 km buffer applied to the road alignment and represented the Local Assessment Area where the field work was prioritised. These points were located within a 2 km buffer along the A8 Highway from Rironi to Mau Summit. Another 64 sampling points were added for the second survey as a range of points to choose from along the A8 South Highway section (B3 & C88) between Rironi and Naivasha. When confronted with a large and complex study area and faced with time and manpower limitations, Bourgeron et al. (2001) recommend that a representative section of the study area, representing a minimum of at least 5% of the total study area, needs to be visited in greater depth. When using a sampling grid cells system to represent the landscape of concern, this means that from the total number of grid cells that represent the study area, at least 5% of the grid cells need to be visited and used to lay at least one research location. However, a target of 10% is suggested as closer to what should be considered for an "optimal" overview. The effort therefore targeted visiting a minimum of 49 sampling grid cells and an optimal target of 98 sampling grid cells sampled within which at least 110 survey sites were planned.

These sampling points served to direct the various biodiversity teams to areas throughout the study area so that representative habitat, vegetation, land cover and sensitivity classes would be surveyed. A target of 110 sampling sites were set as a minimum target to reach using the combined effort of the two herpetofauna survey seasons. The general strategy was to spend a minimum of 30 minutes at each sampling site. Some of the more heterogeneous sites took longer (up to two hours) to survey, whereas searches at homogenous sites or sites with radically transformed habitat (e.g. ploughed or fallow fields) were usually concluded within 30 minutes. In addition to surveying examples of predetermined sampling points, several other 'new' sampling sites were also investigated. This was done on an ad hoc basis when potentially productive or otherwise interesting habitat nodes were noticed. These included three transects along road-side rocky ridges and two road-side trenches.

The bulk of active searching took place during the day, but a few sampling points were also surveyed at night. Active searching entailed crisscrossing of the terrain to target varied terrestrial and wetland habitat types, including suitable microhabitats such as rocks and rock cracks, logs on ground, trunks of trees, leaf-litter, burrows, etc. Many of the sites were in inhabited areas, were features like gardens, hedges, buildings, piles of building material and artificial wetlands were investigated.

3.1.2. Passive capture at sampling points

A series of 12 trap arrays were deployed as passive capture devices during the second field survey. Each trap array consisted of four pitfall (20-litre buckets) and six double-ended funnel traps that were set in conjunction with plastic drift-fences (see Figure 3). We opted to use the straight-line type as opposed to the Y-shaped type which is also a popular trap array choice, based on the findings of Mendes et al. (2015) that linear arrays tend to be more productive than the Y-shaped alternative. Leaf-litter was placed in each pitfall trap and funnels were covered with vegetation to provide shade for the captured specimens. Traps were checked each morning to remove and record captured specimens. The first set of six trap arrays was deployed during 14 to 20 April, thus representative of six trap-nights. The northern-most three of these were set in public areas and were somewhat prone to being tampered with or vandalised. The other three traps were set in the more secure Soysambu Conservancy. The second set of six trap arrays was deployed during 21 to 25 April, thus representative of four trap-nights. Three arrays were set within the Marula Estates, and the southern-most arrays were set in public areas along the truck road (B3 & C88). Although the primary aim of these trap arrays were to survey herpetofauna, they also captured several species of rodents and shrews which were supplementary records for the mammal survey. Trap array locations are plotted on a map (Figure 4), with habitat descriptions and photos of the 12 trapping sites being presented in Appendix III.

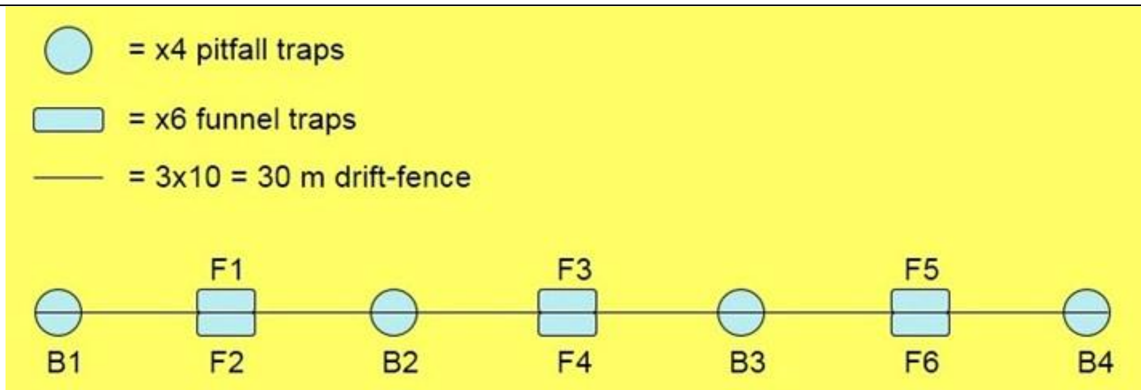


Figure 3: A schematic representation of the straight-line trap array design that was used during the second field survey.

3.1.3. Incidental records

Various members of the FFMES encountered reptiles or amphibians whilst conducting their respective fieldwork. Such incidental observations were usually recorded in the form of photographs or sometimes specimens that were handed to the herpetology team. The most productive source of incidental records were the by-catch of tadpoles and frogs from the freshwater team.

3.1.4. Interviews with local people

The occurrence of a few reptile species that were not recorded during the two 2021 surveys were confirmed in conversation with Henry Ole Sano, a field officer at Soysambu Conservancy. These were incorporated in the reptile checklist for the Nairobi-Nakuru-Mau Summit Highway Project (Appendix I; Table 10).

3.1.5. Data recording

Geographical coordinates were recorded for each observation, together with other relevant field data such as abundance, age-class and habitat. These observations were recorded in the following ways:

- Sight records: Where specimens were observed and identified in the field, but no evidence were collected to verify such observations.
- Photo records: Most specimens observed in the field were photographed, usually in situ.
- Sound records: Digital recordings of frog calls were made for a few species. Such recordings are useful for the identification of cryptic or taxonomically problematic species.
- Voucher records: A number of specimens (including tadpoles) were collected as reference material and were deposited with the Nairobi National Museum (NNM).
- Genetic records: Tissue samples were taken of the voucher material, for future molecular analyses.

3.1.6. Species identification

In addition to the species identifications that were made in the field and the subsequent examination of the voucher specimens that were deposited with the NNM, digital images and sound-clips of problematic taxa were sent to a number of international herpetologists. The following persons provided assistance in this regard:

- Alan Channing (South Africa).

- Beryl Bwong (Kenya).
- Patrick Malonza (Kenya).
- Steve Spawls (United Kingdom).
- Jean-Francois Trape (Senegal).

3.1.7. Field surveys – stated limitations

The COVID 19 pandemic situation led to a limitation on field work effort at night during the two survey periods. The curfew in Kenya was set between 22h00 pm and 4h00 am during the first season (February), and between 20h00 and 4h00 am during the second season (April). This presented a significant restriction on the amphibian work where listening to calls at night and searching areas where calls are heard represent one of the main sampling methods.

The Survey seasons were planned to represent the dry (February) and wet (April) seasons. However, the onset of rains was late in April, and adequate rains were only noted during the last two days of field work. In terms of rain accumulation, local weather reports heard during the April period highlighted that the month of April 2021, until the 24th of April, was drier than the month of February 2021. As both the amphibians and reptiles are highly sensitive to rainfall, the study is unfortunately not considered as representative of the full potential of species during the rainy season.

Most of the sampling points that were investigated are situated in inhabited peri-urban and rural settings, where we had to interact with the local communities for permission to access specific land portions or had to explain to curious persons what we were doing. The time used on interactions and conversations is time not available for surveying, and thus it is listed here as a notable study limitation.

3.2. Desktop survey

3.2.1. Species/locality records from other data sources

The two FFMES 2021 field surveys provided the main data for confirmed species occurrence along the two buffered road transects. These records were then supplemented with records obtained from other digital data sources. The primary data sources were:

- VertNet (http://vertnet.org/).
- Global Biodiversity Information Facility (GBIF; https://www.gbif.org/).
- Nairobi National Museum (NNM).
- iNaturalist (https://www.inaturalist.org/). A project was established on iNaturalist to consolidate the records within the Nakuru and Kiambu counties – https://www.inaturalist.org/projects/herpsnakurukiambukenya – although the records obtained during two FFMES surveys have yet to be uploaded (pending permission being granted by WSP).

3.2.2. Species checklists for the study area

Species checklists of reptiles and amphibians that are known to occur or may potentially occur within the Nairobi-Nakuru-Mau Summit Highway Project study area were prepared (Table 4). Species of confirmed occurrence were based on the records obtained from the two surveys in 2021 and from the four digital data sources. Species of potential occurrence were determined by consulting these four digital data sources to check which other species have been recorded from the general region, i.e. within about 50 km of the study area. Likewise, various books (e.g. Spawls et al. 2018, 2019, Channing & Rödel 2019) and scientific articles were examined to interpret generalised or point-locality distribution maps. Other sources of distribution data that were consulted include:

- IUCN Red List of Threatened Species (https://www.iucnredlist.org/.
- Kenya Reptile Atlas (Bwong et al. undated) http://www.kenyareptileatlas.com/.

The family-level snake taxonomy that was used to compile the checklist is according to Zaher et al. (2019), whereas the genus/species-level reptile taxonomy mostly follows the RDB (Uetz et al. 2021). The taxonomy of the amphibian checklists follows the ASW (Frost 2021).

3.2.3. Species checklists for Kenya

Country checklists of reptiles and amphibians were prepared to serve as context for the herpetofauna species composition of the Nairobi-Nakuru-Mau Summit Highway Project (Appendix I and II, Tables 10 & 11). This entailed the downloading of unedited checklists for Kenya from the following two online sources:

- The Reptile Database (RDB; Uetz et al. 2021): http://reptile-database.org/.
- Amphibian Species of the World (ASW; Frost 2021): https://amphibiansoftheworld.amnh.org/.

These raw checklists were close to being accurate and complete, but they still had to be tweaked to incorporate new species or conflicting distribution records. As such, the relevant literature was scrutinised to update these checklists. For example, articles describing a new species of lizard (Malonza et al. 2021) from Kenya and two new species of snakes (Greenbaum et al. 2021) that also occur in Kenya were described in February and April 2021 respectively.

3.2.4. Species with special status

Most of the herpetofaunal species that may potentially occur within the study area will likely be widespread and common, and generally not of special significance in the context of the proposed highway project. However, some species may be regarded as being species of special significance or species with special status because:

- they may be threatened species as per the IUCN Red List conservation status;
- or they may have relatively small distribution ranges, i.e. they are range-restricted species;
- or they may regional (East African) or national (Kenyan) endemics;
- or they may be listed as protected as per the Kenya Wildlife Service's Wildlife Conservation and Management Act (2012);
- or they may be keystone species, e.g. Nile Crocodile.

The most relevant source for global species conservation status is the IUCN Red List of Threatened Species. This database was consulted during May/June 2021, to check for the most current listings for the herpetofauna of the Nairobi-Nakuru-Mau Summit Highway Project. This online source is fairly complete and up to date for amphibian species, but much of the African reptile fauna have not yet been formally assessed. The IUCN categories of threat applicable to this study are as follow:

- Critically Endangered (CR) – Extremely high risk of becoming extinct in the wild.
- Endangered (EN) – Very high risk of becoming extinct in the wild.
- Vulnerable (VU) – High risk of becoming extinct in the wild.
- Near Threatened (NT) – Likely to become threatened in the near future.
- Least Concern (LC) – Does not qualify for a category of threat. Widespread and abundant taxa are included in this category.
- Data Deficient (DD) – Not enough data to make an assessment of its risk of extinction.
- Not Evaluated (NE) – Has not yet been evaluated against the IUCN criteria.

Details of species with special status in the context of the Nairobi-Nakuru-Mau Summit Highway Project are presented in section 4.2.5

3.2.5. Species accumulation curves

Reptile and amphibian species accumulation curves (SAC) were generated for all data points combined for the wet season and dry season surveys combined. A logarithmic function was fitted (Thompson et al., 2003) to the actual data curve plot to determine sampling sufficiency/adequacy, which was assumed as the point where adding one survey day would yield <1 additional species (Brewer & McCann, 1982) while data were satisfactorily explained by the regression (R^2>0.90). A per day figure was used here as the effort is representing all techniques combined during a day of effort by the herpetology team.

3.2.6. Herpetofaunal guilds

Guilds are an ecological grouping of species where groups are defined by similar ecology (Wilson 1999). For the purpose of our survey we grouped reptiles into five simplified guilds based on their respective resource partitioning affinities, or in other words according to the preferred habitat types for their nutritional, thermoregulatory, shelter or breeding requirements. These reptilian guilds are not necessarily exclusive, with generalist species being members of more than one guild while habitat specialists are typically restricted to a single guild. Amphibians were placed into one of three exclusive guilds based on their main breeding habitat requirements, and then further assigned a combination of non-exclusive 'sub-guilds' based on a combination of microhabitat habitat requirements. These 'sub-guilds' are based on the microhabitat distinctions defined in Du Preez and Carruthers (2017). The reptile and amphibian guilds are summarised below.

3.2.7. Reptile guilds

- **Terrestrial (RG1)**: The majority of reptile species from our survey are associated with terrestrial habitats. Although some of these animals may occasionally utilise rocky outcrops, wetlands or tree/bush habitats, they are not dependent on or strongly associated with these.
- **Aquatic (RG2)**: Members of the aquatic guild are reliant on water bodies and surrounding riparian vegetation. The aquatic guild has few reptiles that are purely aquatic and the majority of species in this guild overlap into other guilds.
- **Arboreal (RG3)**: Reptiles of the arboreal guild are reliant on trees and shrubs. Even though these animals may occasionally utilise terrestrial or aquatic situations, they do not naturally occur in habitats without trees or shrubs.
- **Fossorial (RG4)**: Reptiles that tend to be burrowing in behaviour, i.e. they readily burrow into loose substrate where they spend the bulk of their time, are considered to be fossorial. These reptiles spend the majority of their time underground and are dependent on and thus strongly associated with the subterranean environment. Some fossorial species may frequently emerge to forage, disperse or search for mates above ground regularly, while others may emerge only in exceptional circumstances (flooding, drought, mechanical disturbance etc.). Terrestrial reptile species that may shelter or hunt in small mammal burrows are not included in this guild.
- **Rupicolous (RG5)**: This guild includes all reptiles that are dependent on rocky structures features such as loose rocks, boulders, rocky outcrops, cliffs and ridges. These reptiles are often associated with particular types of rocks and geological formations, and may have morphological adaptation such as flattened bodies to accommodate their lifestyles. Some rupicolous species are able to colonise man-made structures such as buildings.

3.2.8. Amphibian guilds

- **Terrestrial (AG1)**: The terrestrial amphibian guild is comprised of frogs that spend the majority of their lives on ground level, and they from this level when breeding. Most member of this guild typically forage and live away from water bodies when not breeding, but tend to congregate at water bodies during the breeding season. They may shelter under rocks, logs, amongst vegetation and underground, with many species aestivating during the dry season. Although some members of this guild (e.g. *Amietia* species) have strong affinities with wetlands throughout the year, they are still considered to be terrestrial because they spend most of their lives on land as opposed to in the water.
- **Aquatic (AG2)**: Aquatic amphibians are species that typically lives in water for almost all of their lives, only emerging onto land during dispersal events, and even then usually in wet conditions. Aquatic frogs call, breed, feed and shelter beneath the water surface.
- **Arboreal (AG3)**: This guild includes frogs that utilise elevated structures in their environment for breeding. This includes species that call from elevated positions on vegetation, or that use vegetation (including trees) as structures for oviposition. These amphibians are generally dependent on emergent structures for breeding, however they may forage and shelter away from arboreal situations.
- **Endorheic (a)**: These systems are depressions that fill up seasonally (rainwater or seepage) and are depleted by evaporation or absorption into the atmosphere (i.e. pans, pools and ponds).

- **Riverine (b)**: Systems that are generally contained in a channel but may flood during periods of excessive rainfall (i.e. permanent rivers, dry river beds, floodplains, temporary streams, perennial streams and mountain torrents).
- **Lacustrine (c)**: Systems that are larger than 8 ha in topographic depressions with the majority of the water surface open without emergent vegetation (i.e. dams and lakes).
- **Palustine (d)**: Shallow marshland systems dominated by emergent vegetation (i.e. vlei, hill slope seepage, inundated grassland).
- **Terrestrial (e)**: These are systems with no obvious standing or flowing water (i.e. forest floor, rocky outcrops, sand dunes, open grassland, savannah). Species in this sub-guild do not need standing water to breed and are therefore of rare occurrence in amphibians.

4. RESULTS

4.1. Field survey results

4.1.1. Summary of field survey

A concise summary of the field results is presented in Table 2, with more details presented in the various sections of this report.

Table 2: Summary of results of two herpetofaunal surveys that were conducted during February and April 2021.

Survey details	Survey 1	Survey 2	Survey 1&2
No. of survey days	10	12	22
No. of grids surveyed (traps, search & incidental)	55	92	127
No. of sample sites surveyed by active searching	74	120	157
No. of sites surveyed by trap arrays	-	12	12
No. of trap days	-	600	600
No. of reptiles recorded from traps	-	10	10
No. of amphibians recorded from traps	-	13	13
No. of reptile species recorded from traps	-	6	6
No. of amphibian species recorded from traps	-	5	5
% of all recorded reptile species captured in traps	-	21.4%	21.4%
% of all recorded amphibian species captured in traps	-	29.4%	29.4%
Total no. of reptile records/observations	153	303	456
Total no. of amphibians records/observations	100	172	272
Total no. of reptile species (traps, search & incidental)	11	27	28
Total no. of amphibian species (traps, search & incidental)	9	15	15

4.1.2. Spatial sampling overview – overall results

Physical sampling took place in 127 sampling grid cells of the 980 sampling grid cells represented by the study area, thereby exceeding the suggested optimal 10% requirement. A further 245 additional grid cells were visited through the required driving to reach sites and explore the study area. Combined, this means that 38% of the study area was effectively visited and sampled. This spatial overview is summarised in Figures 4 and 5.

4.1.3. Results of active searching at sampling points

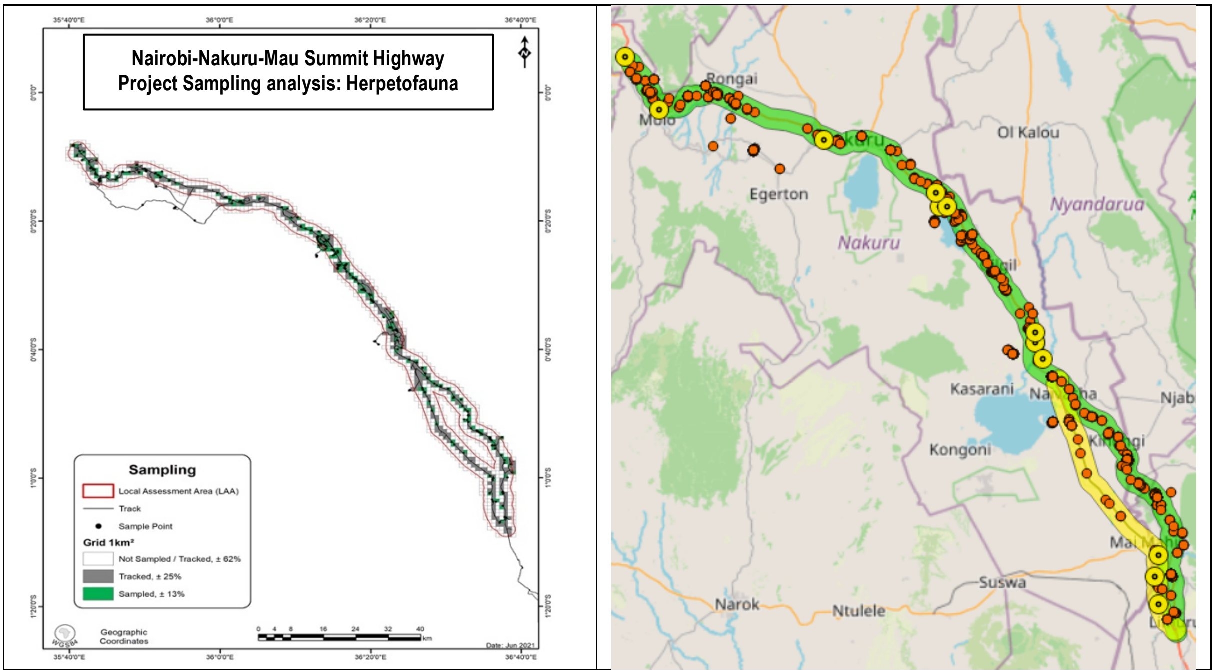
In the process of trying to meet the sampling point survey targets, the herpetofaunal team ended up visiting a wide spectrum of habitat types representative of the study area, A total of 535 observations comprising 25 species of reptiles and 13 species of amphibians were made during the active searching stints (Appendix IV, Table 12). In most cases these observations were of single specimens. Multi-specimen observations were also made, e.g. frog choruses and batches of tadpoles. A total of approximately 1370 specimens were observed during the active searching of sampling sites.

4.1.4. Results of passive capture at sampling points

Results of the 12 trap arrays that were deployed during the April 2021 survey are summarised in Table 3. The traps did not perform particularly well, with only 23 specimens of 11 species sampled during a trap-effort of 600 trap-days. The traps did however contribute two species (7%) of reptiles that were not encountered during the active searching stints or from incidental records. A few of the trap arrays incurred various disturbances, e.g. some were trampled by domestic livestock, one trap was ripped by a wild carnivore, and a few arrays were vandalised by people. Additionally, the so-called wet season was drier than expected and this was likely the main reason that the trap arrays were not very productive.

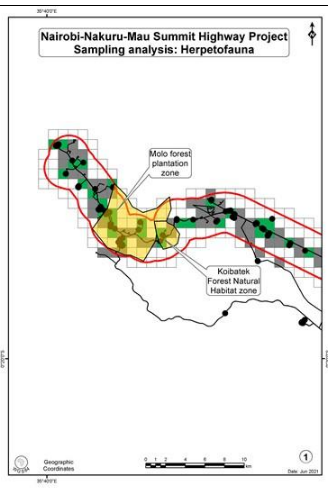
4.1.5. Incidental and interview records

The contributions of incidental records are noteworthy. Most of these were obtained whilst moving between sampling sites, therefore inadvertently improving on the spatial coverage. Several other members of the FFMES biodiversity team also recorded opportunistic records of reptiles and amphibians in the course of their respective surveys. The most valuable source of these was the freshwater team that sampled frogs and tadpoles as a by-catch. Collectively the incidental contributions added 170 observations of 22 species (Appendix IV, Table 12), of which 2 (7%) were not recorded by means of active searching or trapping.

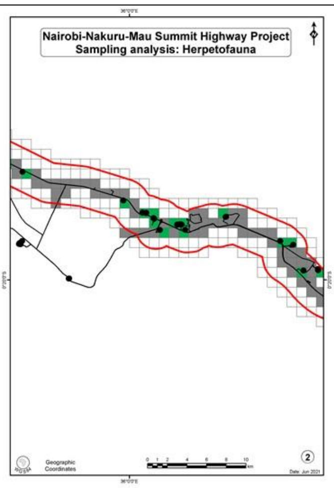


a) b)

Figure 4: Herpetofaunal spatial sampling sufficiency overview for the Nairobi-Nakuru-Mau Summit Highway Project study area, with grey grid cells representing areas tracked, green grid cells areas sampled and black dots herpetofaunal observations (a). The positions of the 12 trap arrays (yellow circles) are plotted in relation to all sampling points (orange dots) where herpetofaunal observations were recorded, including a few sampling sites outside of the 2 km buffer zone (b).



a)



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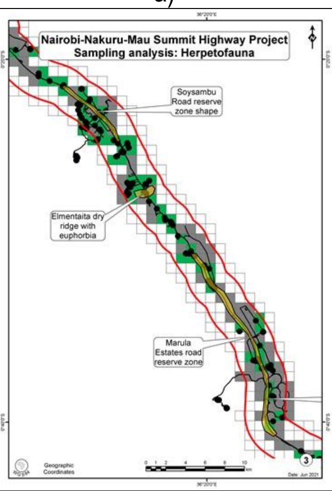
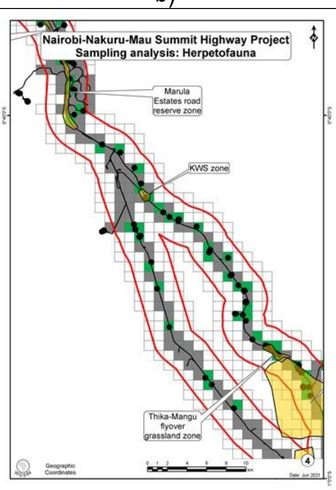


c)



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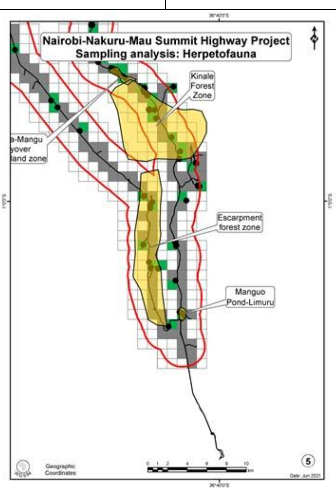


e)

Figure 5: Herpetofaunal spatial sampling sufficiency overview for the Nairobi-Nakuru-Mau Summit Highway Project study area, with grey grid cells representing areas tracked, green grid cells areas sampled and black dots herpetofaunal observations. The special zones of interest are also represented in this figure.

Table 3: Trapping results for reptiles and amphibians of the wet season survey that was conducted during the period 13 to 25 April 2021. The trap dates are presented as MM/DD 2021. Total trap-days are calculated as the number of trap-nights multiplied with the number of traps per array (each array has 10 traps).

Trap arrays	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	All arrays
First trap-day	04/14	04/14	04/14	04/14	04/14	04/14	04/21	04/21	04/21	04/21	04/21	04/21	04/14
Last trap-day	04/20	04/20	04/20	04/20	04/20	04/20	04/25	04/25	04/25	04/25	04/25	04/25	04/25
Total trap-days	60	60	60	60	60	60	40	40	40	40	40	40	600
REPTILIA													
Adolfus jacksoni	–	–	–	–	1	–	–	–	–	–	–	–	1
Duberria atriventris	–	–	–	–	–	–	–	–	1	2	–	–	3
Gerrhosaurus flavigularus	–	–	–	1	–	–	–	–	–	–	–	–	1
Hemidactylus squamulatus	–	–	–	–	–	–	–	–	–	–	1	–	1
Leptotyphlops merkeri	–	–	–	–	1	2	–	–	–	–	–	–	3
Psammophis mossambicus	–	–	–	1	–	–	–	–	–	–	–	–	1
AMPHIBIA													
Amietia wittei	1	–	–	–	–	–	–	–	–	–	–	–	1
Phrynobatrachus keniensis	–	–	–	–	–	–	–	1	1	–	–	–	1
Sclerophrys garmani	–	–	–	–	5	–	–	–	–	–	1	–	6
Sclerophrys kerinyagae	–	2	–	–	–	–	–	–	–	–	–	–	2
Tomopterna cryptotis	–	–	–	–	1	–	–	–	–	–	1	–	2
Total number of herp captures	1	2	0	2	8	2	0	1	2	2	3	0	23
Daily capture rate for all herps	0.02	0.03	0.00	0.03	0.13	0.03	0.00	0.03	0.05	0.05	0.08	0.00	0.04

4.2. Desktop survey results

Field observations were supplemented with records obtained from various other data sources:

- **VertNet**: A download of VertNet reptile and amphibian records for Kenya produced 11,348 and 14,087 records respectively. Most of the VertNet records are very old or undated, with only 22 (0.2%) of the reptile and 167 (1.2%) of the amphibian records being from the period 2000 to June 2021. Much of the records are imprecisely georeferenced (e.g. centroids for vague locality details), or without any locality information whatsoever. Much of the taxonomy is outdated and some specimens have been incorrectly identified. In spite of these data limitations a subset of records were of relevance to the Nairobi-Nakuru-Mau Summit Highway Project study area, and were useful in projecting the potential herpetofaunal species composition and richness of this region.
- **GBIF**: A download of GBIF reptile and amphibian records for Kiambu and Nakuru counties produced 506 and 324 records respectively. Much of the GBIF records are old or undated, with only 220 (43.5%) of the reptile and 42 (13%) of the amphibian records being from the period 2000 to June 2021. Some of the records are imprecisely georeferenced, of outdated taxonomy or incorrectly identified. In spite of these data limitations, a subset of records were of relevance to the Nairobi-Nakuru-Mau Summit study area and aided the projecting of potential herpetofaunal species composition and richness of this region.
- **NNM** (Nairobi National Museum): A download of NNM reptile and amphibian records for Kiambu and Nakuru counties produced 173 and 100 records respectively. Much of the NNM records are old or undated, with only 8 (4.6%) of the reptile and 2 (2%) of the amphibian records being from the period 2000 to June 2021. The bulk of the records were without geographical coordinates, and some of the identifications were of outdated taxonomy or indeterminate. A substantial desktop effort was made in collaboration between two of the team members (RVH and BAB) to georeference the locality details and to update old taxonomy. In the end almost all of these NNM records were incorporated in the dataset. A subset of these was of direct relevance to the Nairobi-Nakuru-Mau Summit study area, and others aided in the projecting of potential herpetofaunal species composition and richness of this region.
- **iNaturalist**: A dataset comprising 49 reptile taxa (248 records) and 26 amphibian taxa (64 records) was downloaded from iNaturalist.org for the counties of Nakuru and Kiambu and assessed by team member RVH. The iNaturalist data set's temporal range was relatively contemporary, with only one record from 1998 and the rest dated 2000 to 2021 (99.6%). The raw iNaturalist dataset contained some taxonomic errors and unidentified observations, e.g.13% of reptile records and 29% of amphibian records were not assigned a species level identification. The majority of these were corrected or identified, and were then incorporated into the relevant Nakuru/Kiambu dataset that informed our list of species richness for the study area.

The useable species and distribution records from these data sources were pooled and plotted on maps of the study area (Figures 6 and 7).

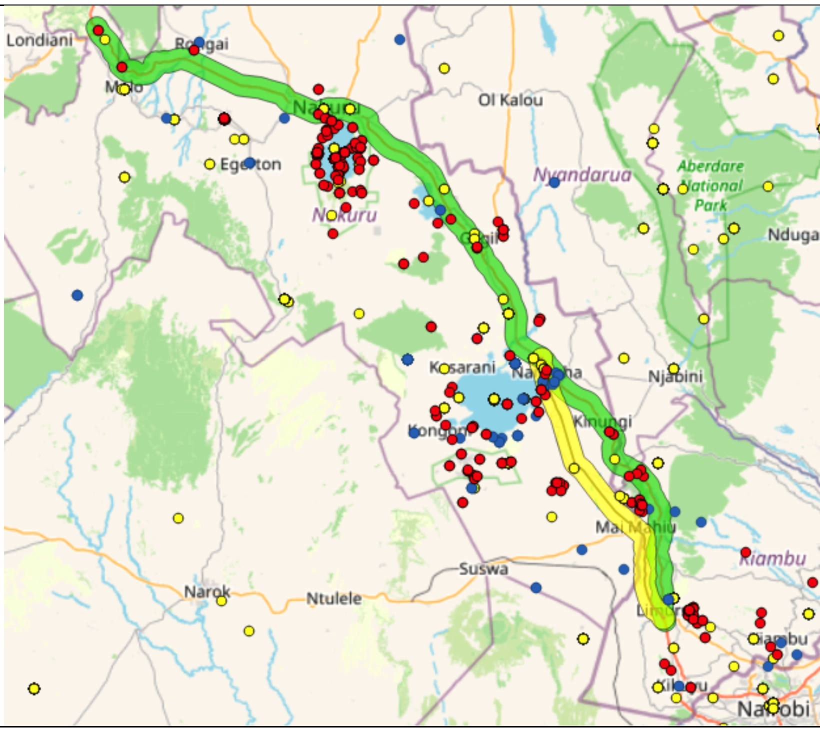


Figure 6: Spatial coverage of reptile records that were derived from other data sources, plotted in the context of the Nairobi-Nakuru-Mau Summit Highway Project study area. Data sources are iNaturalist (red dots), NNM (blue dots), VertNet and GBIF (yellow dots).

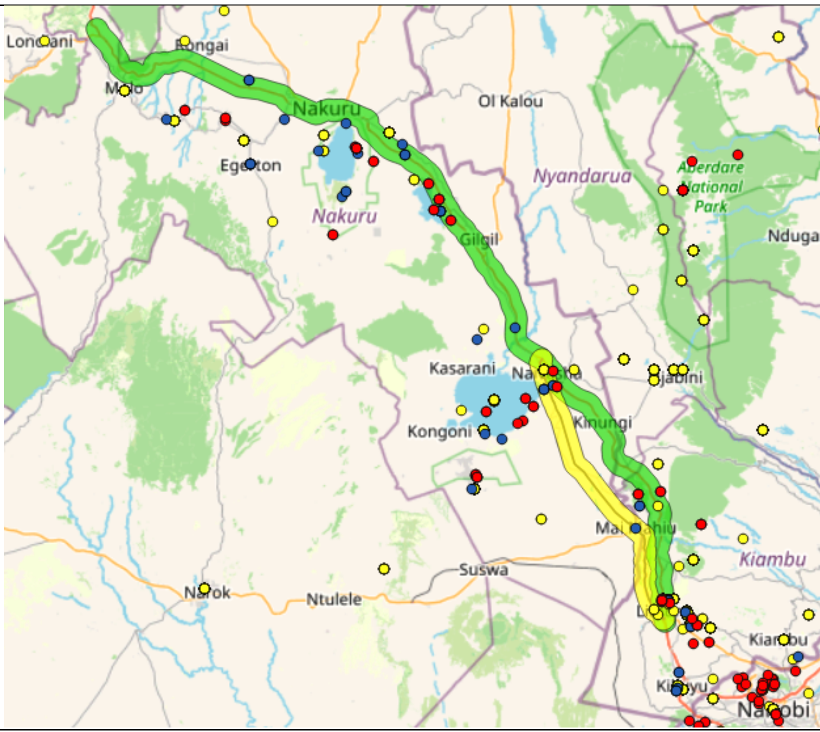


Figure 7: Spatial coverage of amphibian records that were derived from other data sources, plotted in the context of the Nairobi-Nakuru-Mau Summit Highway Project study area. Data sources are iNaturalist (red dots), NNM (blue dots), VertNet and GBIF (yellow dots).

4.2.1. Reptile and amphibian checklists for the study area

The herpetofaunal checklists (Table 4) that were compiled for the study area incorporated records from the two field surveys, plus digital data sets, literature and personal communications. Collectively these add up to the following species richness totals:

- **Reptiles**: 57 reptile species for the study area, comprised of 40 species of confirmed occurrence plus another 17 species of potential occurrence.
- **Amphibians**: 40 amphibian species for the study area, comprised of 18 species of confirmed occurrence plus another 22 species of potential occurrence.

4.2.2. Reptile and amphibian checklists for Kenya

The herpetofaunal checklists (Tables 10 and 11) that were compiled for Kenya are as follow:

- **Reptiles**: 271 species, comprised of 11 chelonians, 1 crocodile, 125 lizards and 134 snakes.
- **Amphibians**: 113 species, comprised of 106 frogs and 7 caecilians.

The proportional expected species richness of the study area's various herpetofaunal groups compared against the Kenya country total is as follow (see also Figure 8):

- **Chelonians**: 1 of 11 = 9.1% of the country total.
- **Crocodiles**: 0 of 1 = 0% of the country total.
- **Lizards**: 28 of 125 = 22.4% of the country total.
- **Snakes**: 28 of 134 = 20.9% of the country total.
- **All reptiles**: 57 of 271 = 21% of the country total.
- **Frogs**: 40 of 106 = 37.7% of the country total.
- **Caecilians**: 0 of 7 = 0% of the country total.
- **All amphibians**: 40 of 113 = 35.4% of the country total.

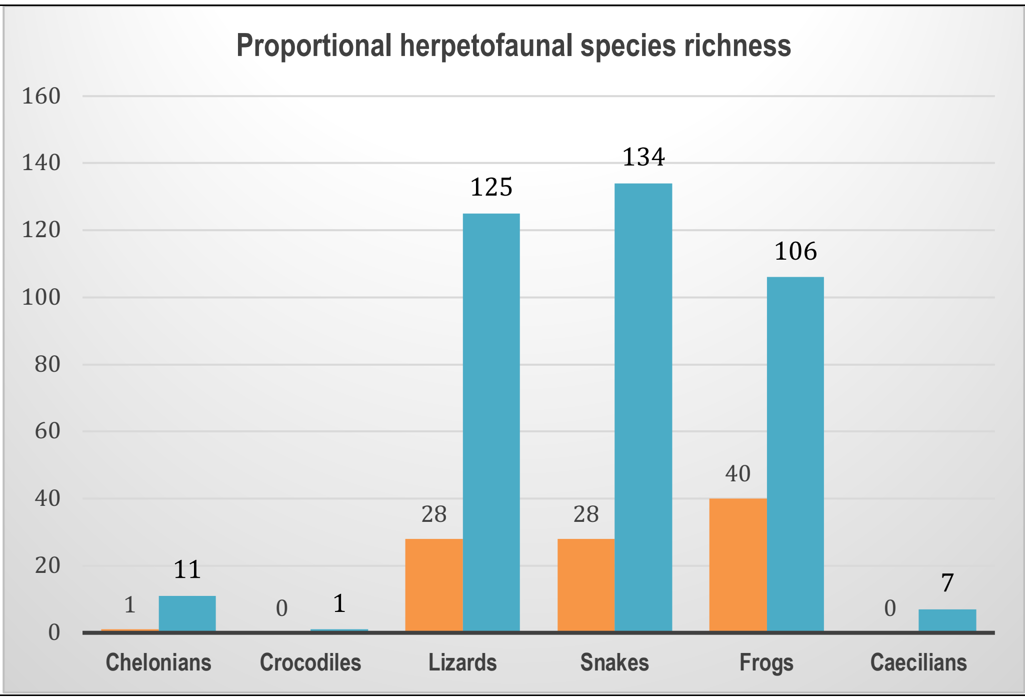


Figure 8: The proportional expected species richness (orange bars) of the study area's herpetofauna presented in comparison with the Kenya country-level richness (blue bars).

Table 4: Summary table of the expected species (species likely to occur) and the sampled species for amphibians and reptiles of the study area.

#	Order	Family	Scientific name	Common name	Conservation status or endemism				Sampled or likely to occur (LTO)	Field campaign		Habitats where the species were surveyed									
					IUCN status	WCMA Status	Kenya Endemic	East African Endemic	LTO species are expected based on prior records in data bases but were not noted during the surveys	Feb-21	Apr-21	Afromontane bamboo	Afromontane rain forest	Afromontane undifferentiated forest	Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	Evergreen and semi-evergreen bushland and thicket	Freshwater swamp	Halophytic vegetation	Riverine wooded vegetation	Upland Acacia wooded grassland	Water bodies
Species likely to occur																					
1	ANURA	Arthroleptidae	*Leptopelis bocagii*	Bocage's Tree frog	LC				LTO						P	P			P	P	
2	ANURA	Bufonidae	*Mertensophryne mocquardi*	Mocquard's Toad	DD		X	X	LTO			P	P	P					P		
3	ANURA	Bufonidae	*Sclerophrys gutturalis*	Guttural Toad	LC				LTO						P	P	P		P	P	P
4	ANURA	Bufonidae	*Sclerophrys kisoloensis*	Kisolo Toad	LC			X	LTO			P	P	P		P					
5	ANURA	Bufonidae	*Sclerophrys pusilla*	Flat-backed Toad	LC				LTO						P	P	P		P	P	P
6	ANURA	Bufonidae	*Sclerophrys regularis*	Common Toad	LC				LTO						P	P			P	P	
7	ANURA	Bufonidae	*Sclerophrys xeros*	Desert Toad	LC				LTO											P	
8	ANURA	Dicroglossidae	*Hoplobatrachus occipitalis*	African Groove-crowned Frog	LC				LTO			P	P	P		P			P	P	
9	ANURA	Hemisotidae	*Hemisus marmoratus*	Marbled Snout-burrower	LC				LTO							P	P		P		
10	ANURA	Hyperoliidae	*Hyperolius cystocandicans*	Silver-bladdered Reed Frog	NT	VU	X	X	LTO						P					P	
11	ANURA	Hyperoliidae	*Hyperolius montanus*	Mountain Reed Frog	LC		X	X	LTO						P					P	
12	ANURA	Hyperoliidae	*Hyperolius pusillus*	Water-lily Reed Frog	LC				LTO							P	P		P	P	
13	ANURA	Microhylidae	*Phrynomantis bifasciatus*	Banded Rubber Frog	LC				LTO							P	P		P	P	
14	ANURA	Phrynobatrachidae	*Phrynobatrachus acridoides*	East African Puddle Frog	LC				LTO							P			P	P	
15	ANURA	Phrynobatrachidae	*Phrynobatrachus kinangopensis*	Kinangop Puddle Frog	VU		X	X	LTO			P	P	P	P					P	
16	ANURA	Phrynobatrachidae	*Phrynobatrachus natalensis*	Natal Puddle Frog	LC				LTO			P	P	P	P	P	P		P	P	
17	ANURA	Phrynobatrachidae	*Phrynobatrachus scheffleri*	Scheffler's Puddle Frog	LC			X	LTO			P	P	P	P					P	
18	ANURA	Pipidae	*Xenopus victorianus*	Mwanza Clawed Frog	LC			X	LTO			P	P	P	P	P	P	P	P	P	P

#	Order	Family	Scientific name	Common name	Conservation status or endemism				Sampled or likely to occur (LTO)	Field campaign		Habitats where the species were surveyed									
19	ANURA	Ptychadenidae	*Hildebrandtia ornata*	African Ornate Frog	LC				LTO							P			P		
20	ANURA	Ptychadenidae	*Ptychadena oxyrhynchus*	Sharp-nosed Frog	LC				LTO			P	P	P	P	P	P		P	P	
21	ANURA	Ptychadenidae	*Ptychadena schillukorum*	Schilluk Grass Frog	LC				LTO								P			P	
22	ANURA	Pyxicephalidae	*Cacosternum kinangopensis*	Kinangop Dainty Frog	LC				LTO											P	
23	ANURA	Pyxicephalidae	*Pyxicephalus adspersus*	Giant Bull Frog	LC				LTO							P				P	
24	ANURA	Pyxicephalidae	*Tomopterna marmorata*	Russet-backed Sand Frog	LC				LTO							P	P		P	P	
25	ANURA	Rhacophoridae	*Chiromantis petersii*	Peter's Foam Nest Frog	LC			X	LTO							P	P		P	P	P
26	SQUAMATA: SAURIA	Agamidae	*Agama lionotus*	Kenya Red-headed Agama	LC				LTO							P				P	
27	SQUAMATA: SAURIA	Chamaeleonidae	*Chamaeleo dilepis*	Common Flap-necked Chameleon	LC				LTO						P	P	P		P	P	
28	SQUAMATA: SAURIA	Cordylidae	*Chamaesaura tenuior*	East African Highland Grass Lizard	NE				LTO											P	
29	SQUAMATA: SAURIA	Gekkonidae	*Hemidactylus angulatus*	East African House Gecko	NE				LTO						P	P			P	P	
30	SQUAMATA: SAURIA	Gekkonidae	*Lygodactylus angolensis*	Angolen Dwarf Gecko	NE				LTO							P			P	P	
31	SQUAMATA: SAURIA	Gekkonidae	*Lygodactylus manni*	Mann's Dwarf Gecko	LC				LTO										P	P	
32	SQUAMATA: SAURIA	Gerrhosauridae	*Gerrhosaurus nigrolineatus*	Black-lined Plated Lizard	NE				LTO						P	P			P	P	
33	SQUAMATA: SAURIA	Lacertidae	*Adolfus kibonotensis*	Kilimanjaro Forest Lizard	NE				LTO			P	P	P	P	P			P		
34	SQUAMATA: SAURIA	Lacertidae	*Nucras boulengeri*	Boulenger's Scrub Lizard	NE				LTO						P	P				P	
35	SQUAMATA: SAURIA	Scincidae	*Leptosiaphos kilimensis*	Kilimanjaro Five-toed Skink	NE				LTO			P	P	P	P				P		
36	SQUAMATA: SAURIA	Scincidae	*Panaspis massaiensis*	Maasai Snake-eyed Skink	NE				LTO						P	P			P	P	
37	SQUAMATA: SAURIA	Scincidae	*Trachylepis irregularis*	Alpine Meadow Skink	NT				LTO						P						
38	SQUAMATA: SERPENTES	Atractaspididae	*Atractaspis irregularis*	Variable Burrowing Asp	LC				LTO			P	P	P	P	P			P	P	
39	SQUAMATA: SERPENTES	Colubridae	*Crotaphopeltis hotamboeia*	White-lipped Snake	NE				LTO			P	P	P	P	P	P	P	P	P	P
40	SQUAMATA: SERPENTES	Colubridae	*Dasypeltis atra*	Montane Egg-eater	NE				LTO			P	P	P	P	P	P	P	P	P	P
41	SQUAMATA: SERPENTES	Colubridae	*Dispholidus typus*	Boomslang	NE				LTO			P	P	P	P	P	P		P	P	
42	SQUAMATA: SERPENTES	Colubridae	*Meizodon semiornatus*	Semi-ornate Snake	NE				LTO							P	P		P	P	P
43	SQUAMATA: SERPENTES	Colubridae	*Thrasops schmidti*	Meru Tree Snake	EN				LTO			P	P	P		P	P		P		
44	SQUAMATA: SERPENTES	Elapidae	*Dendroaspis polylepis*	Black Mamba	LC				LTO						P	P			P	P	
45	SQUAMATA: SERPENTES	Elapidae	*Elapsoidea loveridgei*	East African Garter Snake	NE				LTO						P	P			P	P	
46	SQUAMATA: SERPENTES	Elapidae	*Naja haje*	Egyptian Cobra	NE				LTO						P	P			P	P	
47	SQUAMATA: SERPENTES	Elapidae	*Naja nigricollis*	Black-necked Spitting Cobra	NE	Protected			LTO						P	P	P		P	P	P
48	SQUAMATA: SERPENTES	Elapidae	*Naja subfulva*	Brown Forest Cobra	NE				LTO			P	P	P		P	P		P		P
49	SQUAMATA: SERPENTES	Lamprophiidae	*Lycophidion capense*	Cape Wolf Snake	NE				LTO						P	P			P	P	
50	SQUAMATA: SERPENTES	Lamprophiidae	*Lycophidion ornatum*	Forest Wolf Snake	LC				LTO			P	P	P							
51	SQUAMATA: SERPENTES	Pseudaspididae	*Pseudaspis cana*	Mole Snake	NE				LTO							P				P	

#	Order	Family	Scientific name	Common name	Conservation status or endemism				Sampled or likely to occur (LTO)	Field campaign		Habitats where the species were surveyed									
52	SQUAMATA: SERPENTES	Viperidae	*Bitis worthingtoni*	Kenya Horned Viper	VU				LTO						P					P	
53	SQUAMATA: SERPENTES	Viperidae	*Causus rhombeatus*	Rhombic Night adder	NE				LTO						P	P	P	P	P	P	P
54	TESTUDINES	Testudinidae	*Stigmochelys pardalis*	Leopard Tortoise	LC				LTO						P	P				P	
Sampled species																					
1	ANURA	Bufonidae	*Mertensophryne lonnbergi*	Lönnberg's Toad	VU		X	X	Sampled		X	X	P	P	P				P	P	
2	ANURA	Bufonidae	*Sclerophrys garmani*	Garman's Toad	LC				Sampled	X	X	P	P	X	P	P	P		X	X	P
3	ANURA	Bufonidae	*Sclerophrys kerinyagae*	Kerinyaga Toad	LC	Threatened		X	Sampled	X	X			X	P					P	
4	ANURA	Hyperoliidae	*Hyperolius glandicolor*	Taita Reed Frog	LC				Sampled	P	X	P	P	X	P	P	P		P	P	P
5	ANURA	Hyperoliidae	*Hyperolius viridiflavus*	Common Reed Frog	LC	Protected			Sampled	X	X	P	P	X	X	X	X		P	P	P
6	ANURA	Hyperoliidae	*Kassina senegalensis*	Senegal Running Frog	LC				Sampled	X	X	X	P	X	P	X	P		P	P	
7	ANURA	Phrynobatrachidae	*Phrynobatrachus keniensis*	Kenya Puddle Frog	LC		X	X	Sampled	X	X	X	X	X	X	X			X	P	
8	ANURA	Pipidae	*Xenopus borealis*	Northern Clawed Frog	LC			X	Sampled	X	X	X	P	X	X	P	P		X	X	P
9	ANURA	Ptychadenidae	*Ptychadena anchietae*	Plain Grass Frog	LC				Sampled		X				P	P	P		P	X	P
10	ANURA	Ptychadenidae	*Ptychadena mahnerti*	Mahnert's Ridged Frog	LC			X	Sampled		X	X	P	P							
11	ANURA	Ptychadenidae	*Ptychadena nilotica*	Nile Grass Frog	LC				Sampled	X	X	P	P	X	P	X	X	P	X	P	P
12	ANURA	Pyxicephalidae	*Amietia nutti*	Nutt's River Frog	LC				Sampled	X	X	P	P	X					P		
13	ANURA	Pyxicephalidae	*Amietia wittei*	De Witte's River Frog	LC			X	Sampled	X	X	P	P	X	X	P			P		
14	ANURA	Pyxicephalidae	*Cacosternum plimptoni*	Plimpton's Dainty Frog	LC			X	Sampled	X	X	X	P	X	X	P				P	
15	ANURA	Pyxicephalidae	*Tomopterna cryptotis*	Cryptic Sand Frog	LC				Sampled		X			X	P	P			X	P	
16	SQUAMATA: SAURIA	Agamidae	*Acanthocercus gregorii*	Gregory's Tree Agama	LC				Sampled	X	X			X	P	X		X	X	P	X
17	SQUAMATA: SAURIA	Agamidae	*Agama caudospinosa*	Elementeita Rock Agama	LC				Sampled	X	X			X		X		X	X	P	X
18	SQUAMATA: SAURIA	Chamaeleonidae	*Trioceros bitaeniatus*	Side-striped Chameleon	LC				Sampled	X	X			X	P	X	P		X	X	P
19	SQUAMATA: SAURIA	Chamaeleonidae	*Trioceros hoehnelii*	High-casqued Chameleon	LC	Protected			Sampled	X	X	P	X	X	X	X			P		
20	SQUAMATA: SAURIA	Chamaeleonidae	*Trioceros jacksonii jacksonii*	Jackson's Chameleon	LC	Protected			Sampled		X	X	X	P					P		
21	SQUAMATA: SAURIA	Gekkonidae	*Hemidactylus mabouia*	Tropical House Gecko	LC				Sampled	X	X			X	P	X			X	P	
22	SQUAMATA: SAURIA	Gekkonidae	*Hemidactylus squamulatus*	Nyika Gecko	LC				Sampled		X			X	P	P			P	P	
23	SQUAMATA: SAURIA	Gekkonidae	*Lygodactylus keniensis*	Kenya Dwarf Gecko	LC				Sampled	X	X			X	P	X			X	P	
24	SQUAMATA: SAURIA	Gekkonidae	*Lygodactylus capensis*	Common Dwarf Gecko	LC				Sampled		X					X			P	X	
25	SQUAMATA: SAURIA	Gerrhosauridae	*Gerrhosaurus flavigularus*	Yellow-throated Plated Lizard	NE				Sampled		X				P	X			P	P	
26	SQUAMATA: SAURIA	Lacertidae	*Adolfus jacksoni*	Jackson's Forest Lizard	NE				Sampled	X	X	P	P	X	P	X			X	X	
27	SQUAMATA: SAURIA	Scincidae	*Mochlus sundevallii*	Sundevall's Writhing Skink	LC				Sampled		X			X	P	P			P	P	
28	SQUAMATA: SAURIA	Scincidae	*Trachylepis megalura*	Long-tailed Skink	LC				Sampled		X			X	P		P			P	

#	Order	Family	Scientific name	Common name	Conservation status or endemism				Sampled or likely to occur (LTO)	Field campaign		Habitats where the species were surveyed									
29	SQUAMATA: SAURIA	Scincidae	*Trachylepis striata*	Striped Skink	LC				Sampled	X	X			X	P	X		X	X	X	X
30	SQUAMATA: SAURIA	Scincidae	*Trachylepis varia*	Variable Skink	LC				Sampled	X	X			X	P	X		X	P	P	X
32	SQUAMATA: SAURIA	Varanidae	*Varanus niloticus*	Nile Monitor	NE				Sampled		X			P	P	X	P	P	P		P
33	SQUAMATA: SERPENTES	Atractaspididae	*Aparallactus jacksoni*	Jackson's Centipede Eater	NE				Sampled		X			P	P	X			P	P	
34	SQUAMATA: SERPENTES	Colubridae	*Dasypeltis scabra*	Rhombic Egg-eater	LC				Sampled		X			P	P	X	P		P	P	P
35	SQUAMATA: SERPENTES	Colubridae	*Philothamnus battersbeyi*	Battersby's Green Snake	NE				Sampled		X			P	P	X	P		P	P	P
36	SQUAMATA: SERPENTES	Lamprophiidae	*Boaedon fuliginosus*	African House Snake	NE				Sampled	X	X			X	P	X			P	P	
37	SQUAMATA: SERPENTES	Leptotyphlopidae	*Leptotyphlops merkeri*	Merker's Thread Snake	LC				Sampled	X	X				P	X			X	P	X
38	SQUAMATA: SERPENTES	Psammophiidae	*Psammophis mossambicus*	Olive Sand Snake	NE				Sampled		X			P	P	X	P		P	P	P
39	SQUAMATA: SERPENTES	Psammophiidae	*Psammophis sudanensis*	Northern Stripe-bellied Sand Snake	NE				Sampled		X				P	X				P	
40	SQUAMATA: SERPENTES	Psammophiidae	*Psammophylax multisquamis*	Kenyan Striped Skaapsteker	NE				Sampled		X				P	X				P	P
41	SQUAMATA: SERPENTES	Pseudaspididae	*Duberria atriventris*	Dusky-bellied Slug-eater	NE				Sampled		X	P	P	P	P	X	P		P	P	P
42	SQUAMATA: SERPENTES	Pythonidae	*Python natalensis*	Southern African Rock Python	NE			X	Sampled		X	P	P	P	P	P	P		X	P	P
43	SQUAMATA: SERPENTES	Typhlopidae	*Afrotyphlops lineolatus*	Angola Blind Snake	NE				Sampled	X	X	P	P	P	P	X			P		
44	SQUAMATA: SERPENTES	Viperidae	*Bitis arietans*	Puff Adder	NE	Protected			Sampled		X				P	X			P	P	P

4.2.3. Reptile guilds

The reptile richness for Kenya is approximately 271 species (Appendix I; Table 10). The projected reptile richness of the study area is a subset of about 57 species (about 21% of the Kenya total), and is comprised of one chelonian, 28 snakes and 28 lizards. These can be grouped into five lifestyle affinity guilds as defined in Section 3.2.7, and are summarised in Table 5 and Figure 9. The majority (72%) of the study area have terrestrial affinities, which equates to about half (49%) of the proportional guild makeup. This is generally also the case for the majority of the world's extant reptiles, many of which can be regarded as habitat generalists. The remaining lifestyle affinities are more specialised and thus comprise smaller proportions of the guild makeup. The second largest lifestyle affinity represents species with arboreal affinities, with 35% of species in our study area being tree-living to some extent (= 24% of the proportional guild makeup). Species with rupicolous and fossorial affinities constitute 19% (= 13% proportional guild makeup) and 14% (= 10% proportional guild makeup) of the total respectively, whilst only 5% (= 4% of proportional guild makeup) of reptiles in the study area have aquatic affinities.

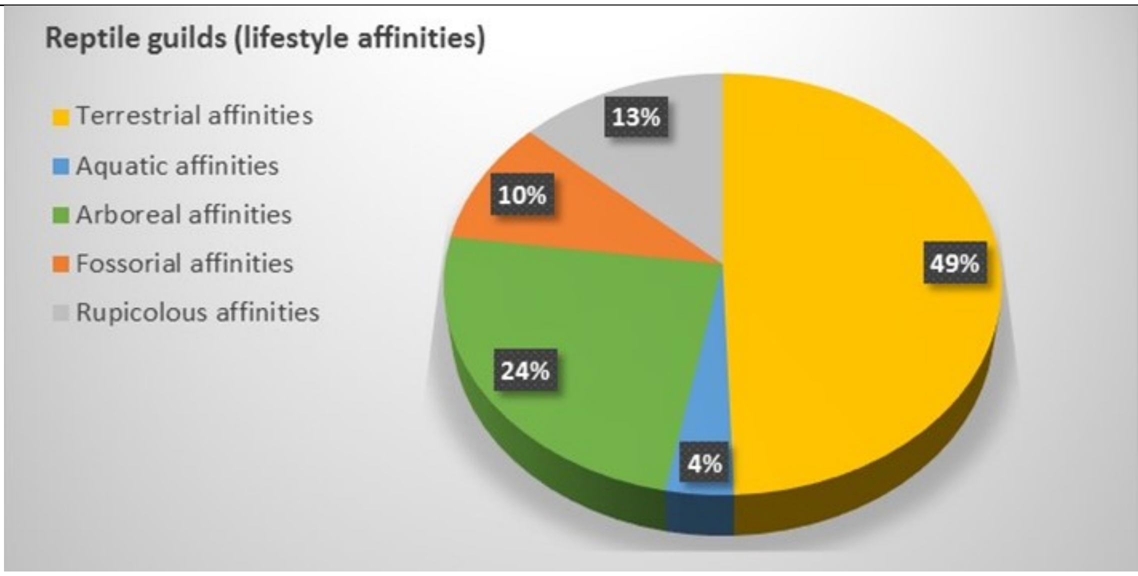


Figure 9: The proportional guild representation of the reptile fauna of the study area.

The various reptile taxon groups are presented here according to the five reptile guilds:

Crocodiles

- **Aquatic reptile guild (RG2):** Crocodiles probably occurred historically in this region when the super lake existed (Spawls & Mathews 2013), but not in living memory. Some crocodiles were apparently released into Lake Naivasha during the 1960's, and it is disputed whether or not any are still present today.

Chelonians

- **Terrestrial reptile guild (RG1):** The occurrence of only one terrestrial tortoise species – the Leopard Tortoise (*Stigmochelys pardalis*) – is known from the study area, and no other species are expected to occur.
- **Aquatic reptile guild (RG2):** With the presence of a well-established system of lakes, it is somewhat puzzling that no aquatic chelonians inhabit this region.

Snakes

The snake fauna of the region is moderately specious and not particularly exceptional for East Africa. A regional novelty is the range-restricted Kenya Horned Viper (*Bitis worthingtoni*), a Kenya endemic. The expected snake species richness for the study area is 28. These can be grouped into guilds as follow:

- **Terrestrial reptile guild (RG1):** 27 of 28 (96%) of the study area's snakes are terrestrial to some degree. They vary tremendously in terms of life-forms, ranging from miniscule thread snakes (Leptotyphlopidae; Figure 10) that averages about 15 cm in length as adults, up to giant pythons that may exceed 5 m in length. Correlated with these size classes are dietary differences, with the small leptotyphlopid snakes feeding on very small invertebrates such as ant larvae and pythons feeding on large prey such as small antelope. Dietary preferences may range from catholic generalists that feed on a variety of different prey types (e.g. cobras may eat small mammals, birds, frogs, lizards, snakes, bird eggs) to diet specialists that feed exclusively on a specific type of prey (e.g. egg-eaters, slug-eaters, centipede-eaters; Figures11a to 11c). Some species are active hunters (e.g. cobras) or ambush predators (e.g. adders). Some are diurnal (e.g. green snakes, sand snakes) or nocturnal (e.g. house snakes; Figure 11d), or both (e.g. pythons, Puff Adder; Figure 11f). Some species are without venom (e.g. wolf snakes), or mildly venomous (e.g. skaapstekers; Figure 11e), or deadly venomous (e.g. mambas, cobras). Several of these terrestrial species also overlap with some of the other guild types.
- **Aquatic reptile guild (RG2):** 2 of 28 (7%) of the study area's snakes are aquatic to some degree, although none are intrinsically aquatic.
- **Arboreal (RG3):** 5 of 28 (18%) of the study area's snakes are arboreal to some degree, although it is only the Boomslang that is foremost an arboreal species.
- **Fossorial (RG4):** 8 of 28 (29%) of the study area's snakes are fossorial or semi-fossorial.
- **Rupicolous (RG5):** Although 2 of 28 (7%) of the study area's snakes have some rupicolous affinities, none are intrinsically rock-living.

<u>Lizards</u>

- **Terrestrial reptile guild (RG1):** In contrast with the snakes that show a near-100% affinity to being terrestrial or semi-terrestrial, less than half (i.e. 46% or 13 of 28) of the study area's lizards are terrestrial to some degree. They vary substantially in terms of life-forms, ranging from small skinks and geckos (Figure 12a) up to the largest of African lizards – the Nile Monitor. Several of the terrestrial lizards also have affinities with other guilds like arboreal or rupicolous habitat.
- **Aquatic reptile guild (RG2):** Only the Nile Monitor (Figure 12b) has a marked affinity with aquatic habitats, i.e. 1 of 28 (<4%).
- **Arboreal (RG3):** 15 of 28 (54%) of the study area's lizards are arboreal to some degree, with the primary members being the four chameleon species that are almost obligatorily arboreal (Figures 12c, d). Although Gregory's Tree Agama is strongly arboreal, the species is seemingly equally at home on rocky habitat (Figures 12e, f).
- **Fossorial (RG4):** 8 of 28 (29%) of the study area's snakes are fossorial or semi-fossorial.
- **Rupicolous (RG5):** 9 of 28 (32%) of the study area's lizards have some rupicolous affinities, the most conspicuous being the two species of rock agamas (Appendix I, Figure 25) that occur in this area.

a) b)

Figure 10: Merker's Worm Snake is by far the smallest snake species in the study area (a & b).


a)


b)


c)


d)


e)


f)

Figure 11: Some snakes have specialised diets, e.g. Rhombic Egg-eater (a), Dusky-bellied Slug-eater (b) and Jackson's Centipede-eater (c). Some snakes have no venom like the African House Snake (d), or are mildly venomous like the Kenyan Striped Skaapsteker (e), or deadly venomous like the Puff Adder (f).

a)

b)

c)

d)

e)

f)

Figure 12: Lizard are diverse in terms of their size and habitat preference, e.g. the Nyika Gecko (a) is a small terrestrial species, the Nile Monitor (b) is very large with aquatic affinities, High-casqued Chameleon (c) and Jackson's Chameleon (d) are arboreal lizards, whereas Gregory' Tree Agama (e & f) inhabits arboreal and rupicolous features.

Table 5: Summary table of the sampled (see field campaign columns) and projected species of reptiles, and their respective guild allocations.

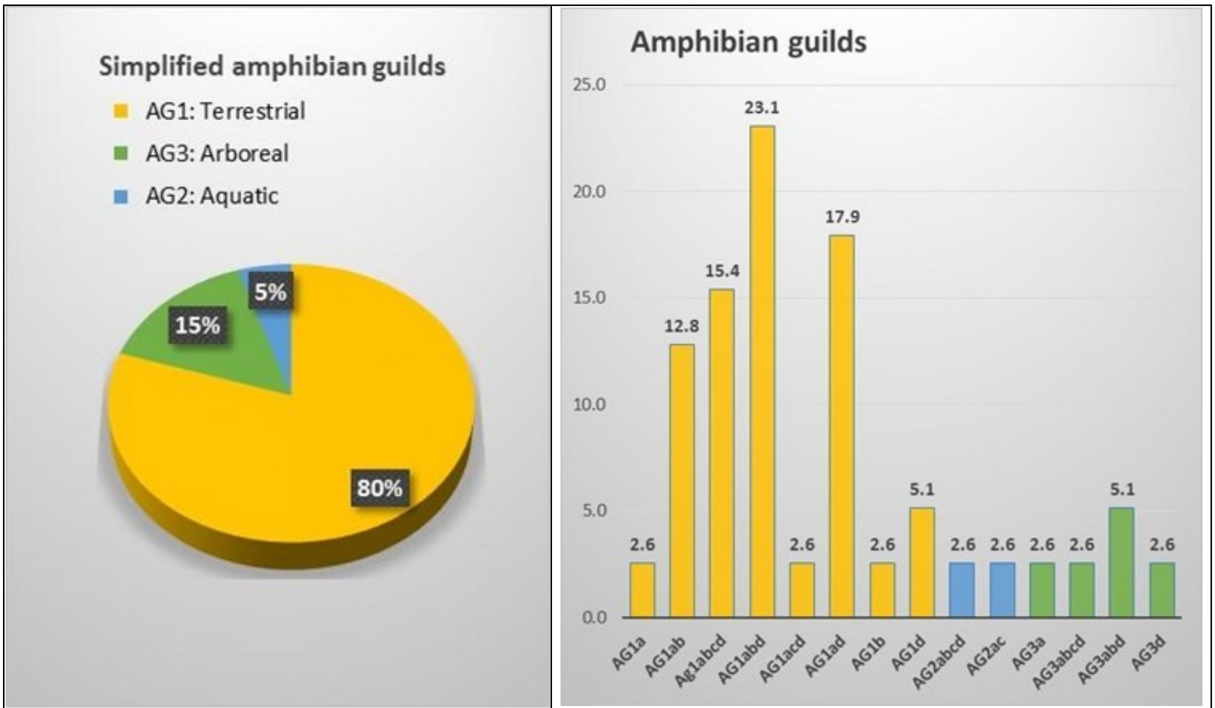
Scientific name	Common name	Field campaign		Reptile guilds (RG)				
		Feb. 2021	April 2021	RG1: Terrestrial	RG2: Aquatic	RG3: Arboreal	RG4: Fossorial	RG5: Rupicolous
TESTUDINES								
Stigmochelys pardalis	Leopard Tortoise			x				
SQUAMATA: SAURIA								
Acanthocercus gregorii	Gregory's Tree Agama	x	x			x		x
Agama caudospinosa	Elementeita Rock Agama	x	x					x
Agama lionotus	Kenya Red-headed Agama							x
Chamaeleo dilepis	Common Flap-necked Chameleon					x		
Trioceros bitaeniatus	Side-striped Chameleon	x	x			x		
Trioceros hoehnelii	High-casqued Chameleon	x	x			x		
Trioceros jacksonii	Jackson's Chameleon		x			x		
Chamaesaura tenuior	East African Highland Grass Lizard			x				
Hemidactylus angulatus	East African House Gecko			x		x		x
Hemidactylus mabouia	Tropical House Gecko		x			x		x
Hemidactylus squamulatus	Nyika Gecko		x	x				
Lygodactylus angolensis	Angolen Dwarf Gecko					x		
Lygodactylus capensis	Cape Dwarf Gecko		x			x		
Lygodactylus keniensis	Kenya Dwarf Gecko	x	x			x		
Lygodactylus manni	Mann's Dwarf Gecko					x		
Gerrhosaurus flavigularis	Yellow-throated Plated Lizard		x	x				
Gerrhosaurus nigrolineatus	Black-lined Plated Lizard			x				
Adolfus jacksoni	Jackson's Forest Lizard	x	x			x		x
Adolfus kibonotensis	Kilimanjaro Forest Lizard					x		x
Nucras boulengeri	Boulenger's Scrub Lizard			x				
Trachylepis irregularis	Alpine Meadow Skink			x				
Trachylepis megalura	Long-tailed Skink		x	x				
Trachylepis striata	Striped Skink	x	x			x		x
Trachylepis varia	Variable Skink	x	x	x				x
Mochlus sundevallii	Sundevall's Writhing Skink		x	x			x	
Leptosiaphos kilimensis	Kilimanjaro Five-toed Skink			x				
Panaspis massaiensis	Maasai Snake-eyed Skink			x				
Varanus niloticus	Nile Monitor		x	x	x	x		

Table 5 (continued)

Scientific name	Common name	Field campaign		Reptile guilds (RG)				
		Feb. 2021	April 2021	RG1: Terrestrial	RG2: Aquatic	RG3: Arboreal	RG4: Fossorial	RG5: Rupicolous
SQUAMATA: SERPENTES								
Aparallactus jacksonii	Jackson's Centipede Eater		x	x			x	
Atractaspis irregularis	Variable Burrowing Asp			x			x	
Crotaphopeltis hotamboeia	White-lipped Snake			x				
Dasypeltis atra	Montane Egg-eater			x		x		
Dasypeltis scabra	Rhombic Egg-eater		x	x		x		
Dispholidus typus	Boomslang					x		
Meizodon semiornatus	Semi-ornate Snake			x				
Philothamnus battersbyi	Battersby's Green Snake		x	x		x		
Dendroaspis polylepis	Black Mamba			x		x		x
Elapsoidea loveridgei	East African Garter Snake			x			x	
Naja haje	Egyptian Cobra			x				
Naja nigricollis	Black-necked Spitting Cobra			x				
Naja subfulva	Brown Forest Cobra			x	x			
Boaedon fuliginosus	African House Snake	x	x	x				
Lycophidion capense	Cape Wolf Snake			x				
Lycophidion ornatum	Forest Wolf Snake			x				
Leptotyphlops merkeri	Merker's Thread Snake	x	x	x			x	
Psammophis mossambicus	Olive Sand Snake		x	x				
Psammophis sudanensis	Northern Stripe-bellied Sand Snake		x	x				
Psammophylax multisquamis	Kenyan Striped Skaapsteker		x	x				
Pseudaspis cana	Mole Snake			x			x	
Duberria atriventris	Dusky-bellied Slug-eater		x	x				
Python natalensis	Southern African Rock Python		x	x	x			x
Afrotyphlops angolensis	Angola Blind Snake			x			x	
Afrotyphlops lineolatus	Lineolate Blind Snake	x		x			x	
Bitis arietans	Puff Adder		x	x				
Bitis worthingtoni	Kenya Horned Viper			x				
Causus rhombeatus	Rhombic Night adder			x				

4.2.4. Amphibian guilds

The amphibian richness for Kenya is approximately 113 species (Appendix II; Table 11), comprising 7 caecilian and 106 frog species. The projected amphibian richness of the study area is a subset of 40 species (about 35.4% of the Kenya total), and is comprised of anurans (frogs) only. None of the limbless caecilian species are likely to occur in the study area. Amphibian guilds as defined in Section 3.2.8 are summarised below as three exclusive (or simplified) guilds that are based on the selection of non-breeding lifestyle (Figure 13a), and the non-exclusive sub-guilds based on breeding site selection plus their microhabitat preferences (Figure 13b). The majority of the amphibians from the study area are members of the terrestrial guild (80%), with arboreal and aquatic species making up 15% and 5% respectively. The more detailed grouping from breeding site selection into microhabitat sub-guilds provides more insights into what kind of wetland habitat types specific species are dependent on. The terrestrial species associated with endorheic, riverine and palustine systems (AG1abd) is the most prominent group in our study area (23.1%). Terrestrial species associated with endorheic and palustine systems (AG1ad: 17.9%), endorheic, riverine, lacustrine and palustine systems (AG1abcd: 15.4%) and endorheic and riverine systems (AG1ab:12%) collectively make up the majority of guilds (67%) and constitute the so-called generalist species, The remainder of the amphibian species form smaller groupings and are the so-called specialist species, i.e. terrestrial species that are only associated with endorheic systems (AG1a: 2.6%), terrestrial species that are associated with endorheic, lacustrine and palustine systems (AG1acd: 2.6%), terrestrial species that are associated with riverine systems only (AG1b: 5.1%), aquatic species that are associated with endorheic, riverine, lacustrine and palustine systems (AG2abcd: 2.6%), aquatic species associated with endorheic and lacustrine systems (AG2ac: 2.6%), arboreal species that are associated with endorheic systems (AG3a%), arboreal species that are associated with endorheic, riverine, lacustrine and palustine systems (AG3abcd: 2.6%), arboreal species that are associated with endorheic, riverine and palustine systems (AG3abd: 5.1%), and arboreal species that are associated with palustine systems (AG3d: 2.6%).



a) b)

Figure 13: The proportional guild representation of the amphibian fauna of the study area, (a) and non-exclusive amphibian sub-guilds based on breeding site selection in combination with microhabitat preferences (b).

The variety of amphibian guild distinctions relate to the potential species richness of a particular landscape, with the richness of specialist species usually being negatively correlated with anthropogenic or homogenous habitats. Conversely, habitat heterogeneity is typically equated with an increase of species richness plus greater representation of specialist (i.e. multi-guild) species. The various frog taxon groups are presented here in the context of amphibian guild divisions:

- **Terrestrial amphibian guild (AG1):** The majority (80%) of frogs of the study area are more terrestrial in their lifestyle than arboreal or aquatic. The various species differ significantly in terms of how much time they spend in close association with wetland features. For example, toads (bufonids Figures 14a,b) in comparison to river frogs (*Amietia*; Figures 15a, b) are much more terrestrial and significantly less associated with waterbodies. Most frogs will specifically associated with wetlands during the actual seasonal breeding events, but then for the bulk of the year they may be several hundred meters away from wetlands. In many cases these terrestrial frogs will also burrow into substrate to aestivate during dry periods.
- **Aquatic amphibian guild (AG2):** Two species (5%) of pipid frogs in the study area are truly aquatic. In-field identifications to distinguish between these two species are difficult. We tentatively identified all of the 2021 survey records as Northern Clawed Frog (Figures 15c, d). The African Groove-crowned Frog was grouped in the terrestrial guild in this assessment, but it can be considered as being at least partially aquatic.
- **Arboreal amphibian guild (AG3):** The six (15%) frog species in the study area with arboreal habits are five species of reed frogs and Peter's Foam Nest Frog. Whereas the Common Reed Frog (Figures 15e, f) is prolific throughout most of the study area, it seems as though the distribution of the Silver-bladdered Reed Frog overlaps only marginally in the southern-most reaches in the region of Limuru/Tigoni.

a) b)

Figure 14: Bufonid frogs like Kerinyaga Toad (a) and Garman's Toad (b) are terrestrial amphibians that spend most of the year not specifically associated with wetland habitats.

Figure 15: Members of the genus *Amietia* (e.g. Nutt's River Frog and De Witte's River Frog) are not aquatic, but they do have a strong year-round affinity with endorheic and riverine wetlands (a & b). The Northern Clawed Frog (c & d) is truly an aquatic species which will spend almost its entire life within a waterbody of some sorts. They will sometimes leave a particular wetland to migrate overland to another. This typically happens when wetlands dry up or during substantial rainfall events. The Common Reed Frog shelters on wetland-vegetation during the day (e & f), and at night the males will perch on vegetation when emitting breeding calls.

Table 6: Summary table of the sampled (see field campaign columns) and projected species of amphibians, and their respective guild and sub-guild allocations.

Scientific name	Common name	Field campaign		Amphibian guilds (AG)							
		Feb. 2021	April 2021	AG1: Terrestrial	AG2: Aquatic	AG3: Arboreal	a: Endorheic	b: Riverine	c: Lacustrine	d: Palustine	e: Terrestrial
ANURA											
Leptopelis bocagii	Bocage's Tree frog			x			x			x	
Mertensophryne lonnbergi	Lönnbergs Toad		x	x			x	x		x	
Mertensophryne mocquardi	Mocquards Toad			x			x	x		x	
Sclerophrys garmani	Garman's Toad		x	x			x	x	x	x	
Sclerophrys gutturalis	Guttural Toad			x			x	x	x	x	
Sclerophrys kerinyagae	Kerinyaga Toad	x	x	x			x		x	x	
Sclerophrys kisoloensis	Kisolo Toad			x			x	x		x	
Sclerophrys pusilla	Flat-backed Toad			x			x	x			
Sclerophrys regularis	Common Toad			x			x	x		x	
Sclerophrys xeros	Desert Toad			x			x			x	
Hoplobatrachus occipitalis	African Groove-crowned Frog			x			x			x	
Hemisus marmoratus	Marbled Snout-burrower			x			x	x			
Hyperolius cystocandicans	Silver-bladdered Reed Frog					x	x				
Hyperolius glandicolor	Gong Reed Frog		x			x	x	x	x	x	
Hyperolius montanus	Mountain Reed Frog					x				x	
Hyperolius pusillus	Waterlily Reed Frog					x	x	x		x	
Hyperolius viridiflavus	Common Reed Frog	x	x			x	x	x	x	x	
Kassina senegalensis	Senegal Running Frog	x	x	x			x	x		x	
Phrynomantis bifasciatus	Banded Rubber Frog			x			x	x		x	
Phrynobatrachus acridoides	East African Puddle Frog			x			x			x	
Phrynobatrachus keniensis	Kenya Puddle Frog	x	x	x			x	x		x	
Phrynobatrachus kinangopensis	Kinangop Puddle Frog			x			x			x	
Phrynobatrachus natalensis	Natal Puddle Frog			x			x	x	x	x	
Phrynobatrachus scheffleri	Scheffler's Puddle Frog			x			x	x	x	x	
Xenopus borealis	Northern Clawed Frog	x	x		x		x	x	x	x	
Xenopus victorianus	Mwanza Frog				x		x		x		
Hildebrandtia ornata	African Ornate Frog			x			x			x	
Ptychadena anchietae	Plain Grass Frog		x	x			x	x		x	
Ptychadena mahnerti	Mahnert's Ridged Frog		x	x			x				
Ptychadena nilotica	Nile Grass Frog	x	x	x			x	x	x	x	
Ptychadena oxyrhynchus	Sharp-nosed Frog			x			x			x	

Table 6 (continued)

Scientific name	Common name	Field campaign		Amphibian guilds (AG)							
		Feb. 2021	April 2021	AG1: Terrestrial	AG2: Aquatic	AG3: Arboreal	a: Endorheic	b: Riverine	c: Lacustrine	d: Palustine	e: Terrestrial
Ptychadena schillukorum	Schilluk Grass Frog			x						x	
Amietia nutti	Nutt's River Frog	x	x	x				x			
Amietia wittei	De Witte's River Frog	x	x	x			x	x			
Cacosternum kinangopensis	Kinangop Dainty Frog			x			x	x			
Cacosternum plimptoni	Plimpton's Dainty Frog	x	x	x			x	x	x	x	
Tomopterna cryptotis	Cryptic Sand Frog		x	x			x	x			
Tomopterna marmorata	Russet-backed Sand Frog			x			x	x		x	
Pyxicephalus adspersus	Giant Bull Frog			x						x	
Chiromantis petersii	Peter's Foam Nest Frog					x	x	x		x	

4.2.5. Species with special status

IUCN: Some 34 of 57 reptile species that may potentially occur within the study area have yet to be evaluated along IUCN criteria, and 21 species are listed as being of LC (see Table 5). In contrast, all of the 40 amphibian species that may potentially occur within the study area have been assessed, with 37 of them being of LC. The only species with special status are two reptiles and three amphibians:

Trachylepis irregularis – NT. The Alpine Meadow Skink is associated with high-altitude (3,000^{+} m) moorland. This species may potentially occur in the general region of the study area, perhaps at the highest reaches of the Mau escarpment. However, it probably does not occur within the 2 km road-buffer Local Assessment Area and as such this species is not deemed to be of consideration in the context of the road upgrading project.

Bitis worthingtoni – VU. The Kenya Horned Viper does occur within the Local Assessment Area, in the region of Naivasha and potentially also on the Mau escarpment. This is the only reptile species with special status in the context of the road upgrading project

Mertensophryne lonnbergi – VU. A small population of Lönnberg's Toad was recorded during the April 2021 survey. A pair in amplexus (Figure 24) and another two males (Appendix IV, Table 12) were observed in flooded terrain about 50 m from the road, thus within the Local Assessment Area. This species probably also occurs as scattered subpopulations at various sites along the A8 Highway south of Naivasha.

Phrynobatrachus kinangopensis – VU. We observed several specimens and calling individuals of puddle frogs (i.e. genus *Phrynobatrachus* during the 2021 surveys, but identification down to species level was somewhat ambiguous. We tentatively assume that all of our records are *P. keniensis*, but more species (including *P. kinangopensis*) could be involved. Based on generalised distribution information, *P. kinangopensis* may possibly occur within the Local Assessment Area to the south of Naivasha.

Hyperolius cystocandicans – NT. The known distribution of the Silver-bladdered Reed Frog overlaps marginally with the study area in the southern-most reaches in the region of Limuru/Tigoni. It is associated with wetlands in open grassveld habitat.

WCMA: The sixth schedule of the Conservation and Management Act (2013) of the Kenya Wildlife Service lists the nationally "Critically Endangered, Vulnerable, Nearly Threatened and Protected" animal species. The WCMA listing contains various discrepancies to the IUCN listing. The following of the listed species are of relevance to the Nairobi-Nakuru-Mau Summit Highway Project:

Python sebae – EN (IUCN = NE). Two cryptic species of large python occur in Kenya, but the WCMA only lists the Central African Rock Python. It is generally quite difficult to distinguish between this species and the similar-looking Southern African Rock Python (see for example the iNaturalist records from the HerpsNakuruKiambuKenya project). According to Spawls et al. (2018), the more likely candidate for the high-altitude region of the study area is *Python natalensis*. We recorded the presence of python in the study area, based on fragments of sloughed skin that were found. It is not essential to know precisely which particular python species (if not perhaps both) occurs in the study area. It is sufficient for the purpose of this study to know that pythons do inhabit this area, and that the conservation status of both species would likely be evaluated as Least Concern once assessed along IUCN criteria.

Phrynobatrachus irangi – EN (IUCN = EN). Although the Irangi Puddle Frog is known from high-altitude montane forest localities on the outskirts of the study area, this species has not yet been recorded close to the A104 road. A much more extensive surveying effort would need to be conducted in this area and beyond to improve on the distribution information of this poorly known species.

Hyperolius cystocandicans – VU (IUCN = NT). The Silver-bladdered Reed Frog is not know from many populations. The species' distribution overlaps marginally with the study area in the southern-most reaches in the region of Limuru/Tigoni.

Sclerophrys kerinyagae (listed as *Bufo kerinyagae*) – Threatened (IUCN = LC). The Kerinyaga Toad is an East African endemic. A few specimens were recorded during the 2021 field surveys.

Hyperolius viridiflavus – Protected (IUCN = LC). The Common Reed Frog is indeed extremely common, and its listing (incorrectly as *Hyperolius marmoratus*) on the WCMA is puzzling. Many specimens were recorded during the 2021 field surveys.

Naja nigricollis – Protected (IUCN = NE). The Black-necked Spitting Cobra is a common species distributed in several African countries. Although not yet evaluated by IUCN, this species would qualify for LC status. It is certainly not a species of special status in terms of conservation status or distribution.

Bitis arietans – Protected (IUCN = NE). The Puff Adder is one of the most common and wide-spread snakes in Africa. Although not yet evaluated by IUCN, this species would qualify for LC status. It is certainly not a species of special status in terms of conservation status or distribution.

Trioceros hoehnelii – Protected (IUCN = LC). The listing of the High-casqued Chameleon as a protected species is presumably due to the popularity of chameleons in the exotic pet trade. It is common within the study area, with >80 specimens observed at numerous localities within the study area.

Trioceros jacksonii – Protected (IUCN = LC). The listing of the High-casqued Chameleon as a protected species is presumably due to the popularity of chameleons in the exotic pet trade. A few specimens were recorded from the southern quarter of the study area.

Bennun et al. (2018) provided a list of reptile and amphibian species (Table 7) that were flagged as being of special significance, with a directive to expend specific focus on these species with special status during the two FFMES 2021 surveys. This was aimed for during the subsequent surveys, and a few of the target species were encountered.

Table 7: The Bennun et al. (2018) list of species that were highlighted as being of special significance for the project, and that were specifically targeted during the field surveys. The likelihood of their respective probability of occurring within the study is shown as Y (= confirmed or of potential occurrence) or N (= not likely to occur).

Scientific name	IUCN	Occur	Remarks
Ptychadena mahnerti	LC	Y	Confirmed occurrence in study area.
Cacosternum kinangopensis	LC	N	Unlikely to co-occur with *C. plimptoni*.
Phrynobatrachus keniensis	LC	Y	Confirmed occurrence; common in study area.
Hyperolius montanus	LC	Y	Not found during surveys, but likely to occur here.
Mertensophryne lonnbergi	VU	Y	Confirmed occurrence in study area.
Mertensophryne mocquardi	DD	Y	Not found during surveys, but may possibly occur.
Phrynobatrachus irangi	EN	N	Unlikely to occur in study area.
Cacosternum plimptoni	LC	Y	Confirmed occurrence; common in study area.
Amietia wittei	LC	Y	Confirmed occurrence; common in study area.
Hyperolius cystocandicans	NT	Y	Not found during surveys, but confirmed occurrence.
Phrynobatrachus kinangopensis	VU	Y	Not found during surveys, but may possibly occur.
Trioceros jacksoni	LC	Y	Confirmed occurrence in study area.
Bitis worthingtoni	LC	Y	Not found during surveys, but confirmed occurrence.

5. DISCUSSION

5.1. Species accumulation curves and sampling efficiency

The spatial sampling summary highlighted that 127 sampling grid cells were the object of at least one sampling site, which indicates that 13% of the sampling area survey grid (980 grid cells of 1 km²) was surveyed. In addition to this figure, a total of 245 additional grid cells were visited through the required driving to reach sites and explore the study area. This represents an additional 25% of the study area that was visited and where both incidental records were taken. This also provided the team the necessary "visual" overview of the area to establish where the typical range of habitat types and variation were encountered and sampled. The spatial sampling effort highlights that 38% of the study area could therefore be sampled or visited, which exceeds the requirements stated by Bourgeron et al. (2001) or Hayek and Buzas (2010) that between 5% and 10% of the number of grid cells in a landscape size study area be visited whether for sampling purposes or for reconnaissance of the land. The study is therefore considered as having sampled the study area in a spatially representative manner.

The official number of survey days were 10 and 12 days for the dry and wet seasons respectively. However, incidental observations made on the first travelling days of each survey were added to the SAC assessments, effectively adding up to 24 survey days (see Figures 16 & 17). As can be noted on the figure representative for reptiles, a sudden spike in species is noted in the last three days of effort, which is a result of the onset of rains at that stage, driving species presence. This is not considered a result of the sampling effort location, as at this stage of the survey period, the herpetological study team had deployed trap arrays all the way between Marula Estates and Rironi and has already conducted searches in that section of the study area. As a result of the late onset of rains, the species accumulation pattern does not fit the actual data plot adequately ($R^2 = 0.77$, which is less than the desired $R^2 = 0.90$, although some published work finds $R^2 = 0.75$ acceptable – see Thompson et al. 2003). The pattern of species emergence was much less pronounced for the amphibians (Figure 17), where the curve fit was much higher ($R^2 = 0.94$) and therefore acceptable to ensure the curve can be used as a suitable predictor of effort measure. In both instances, the tangent between the line highlighting one species added per day of survey and the fitted curve appears to have been achieved during the first period of baseline effort (after 7 days for reptiles and after 5 days for amphibians), thereby indicating that the effort was representative for the periods sampled, which for the purposes of the herpetology sampling effort must be considered as two different snapshots of the dry season.

The late onset of rains did not allow for a satisfactory level of sampling of the wet season, and this cannot be represented here.

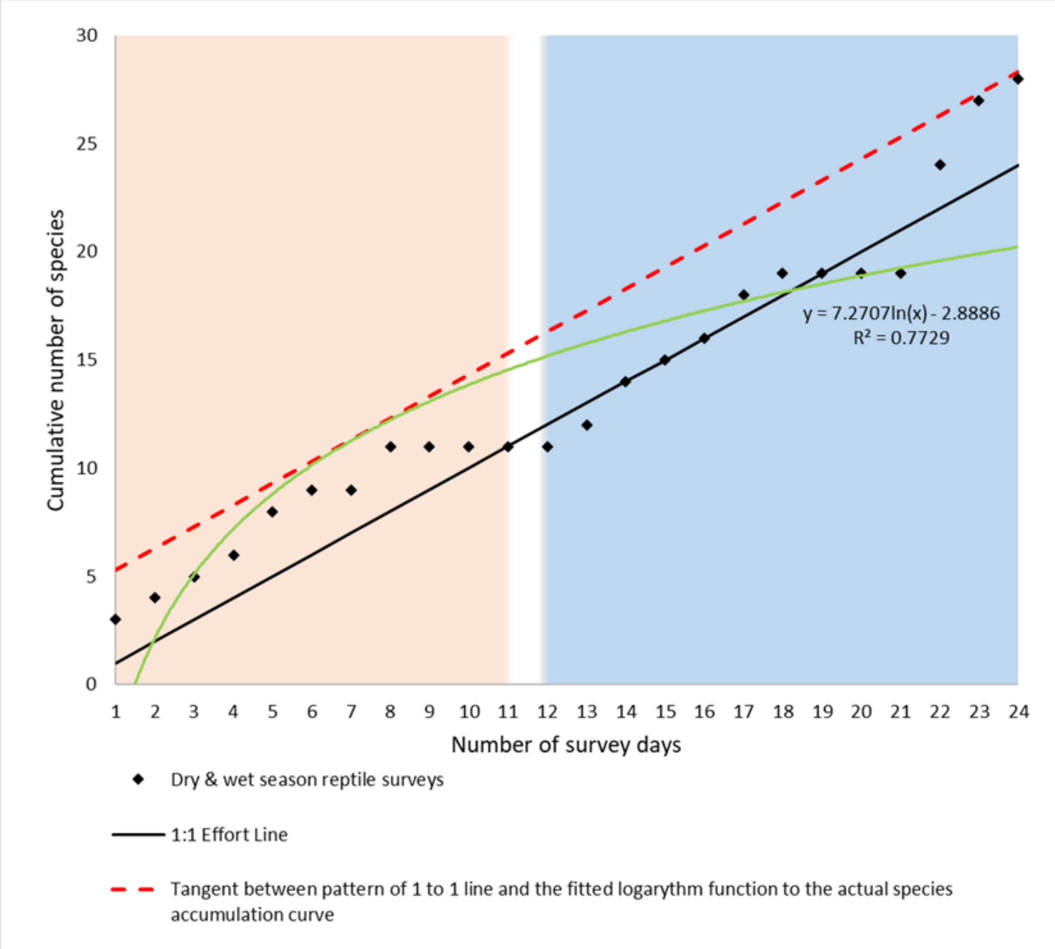


Figure 16: Species accumulation curve for reptiles for dry (pink) and wet (blue) season surveys combined. The green line represents the trend line model fit to the data points (black lozenges). The black line represents the theoretical representation for 1 species added per additional day of effort. The red line represents the 1 to 1 line tangent to the fitted curve.

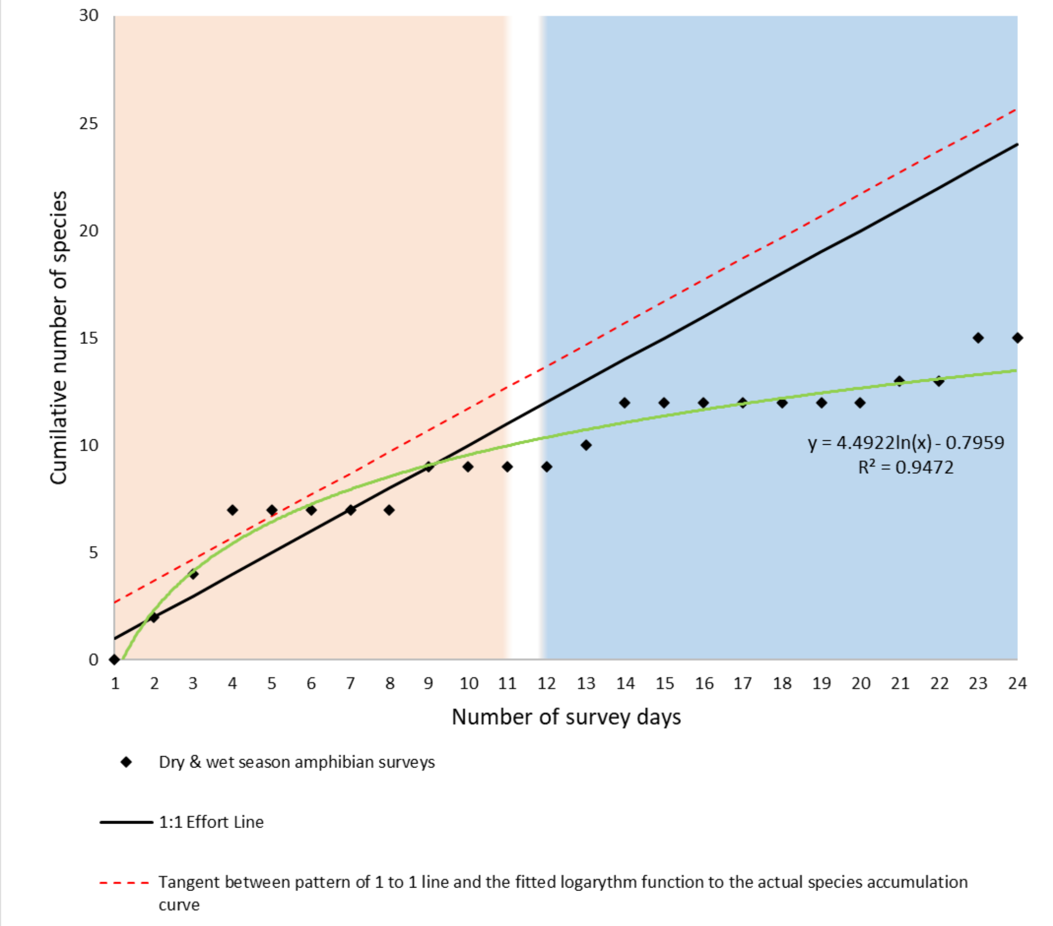


Figure 17: Species accumulation curve for amphibians for dry (pink) and wet (blue) season surveys combined. The green line represents the trend line model fit to the data points (black lozenges). The black line represents the theoretical representation for 1 species added per additional day of effort. The red line represents the 1 to 1 line tangent to the fitted curve.

5.2. Projected species composition as a measure of sampling efficiency

In addition to evaluating the surveying success or comprehensiveness of biodiversity surveys by means of species accumulation curves, it is also useful to compare the recorded species richness with the potential species richness. The latter was determined by means of extrapolations of species geographic distribution information that have been recorded in various literature and digital database sources (see section 4.4). A summary of the sampled herpetofaunal species richness versus the potential herpetofaunal species richness is presented below in Table 8:

Table 8: A summary of herpetofaunal survey representativeness, with the actual species richness as sampled during the two field surveys compared against the total potential species richness as derived from the various literature and digital database sources.

Chelonians: Sampled richness vs potential richness	0 of 1 (0%)
Snakes: Sampled richness vs potential richness	11 of 28 (39.3%)
Lizards: Sampled richness vs potential richness	17 of 28 (60.7%)
Reptiles: Sampled richness vs potential richness	28 of 57 (49.1%)
Amphibians: Sampled richness vs potential richness	15 of 40 (37.5%)

The literature and digital database records were useful to project the potential herpetofaunal composition of the study area, as per Tables 5 and 6. Some of these distribution records were very accurate and could be used to verify the occurrence of additional species that were not encountered during the 2021 field surveys. These records of confirmed occurrence were incorporated in the two Kenya country checklists (Tables 10 & 11). These records contribute one chelonian, six snake, two lizard and three amphibian species to the list of confirmed species for the study area (Table 9).

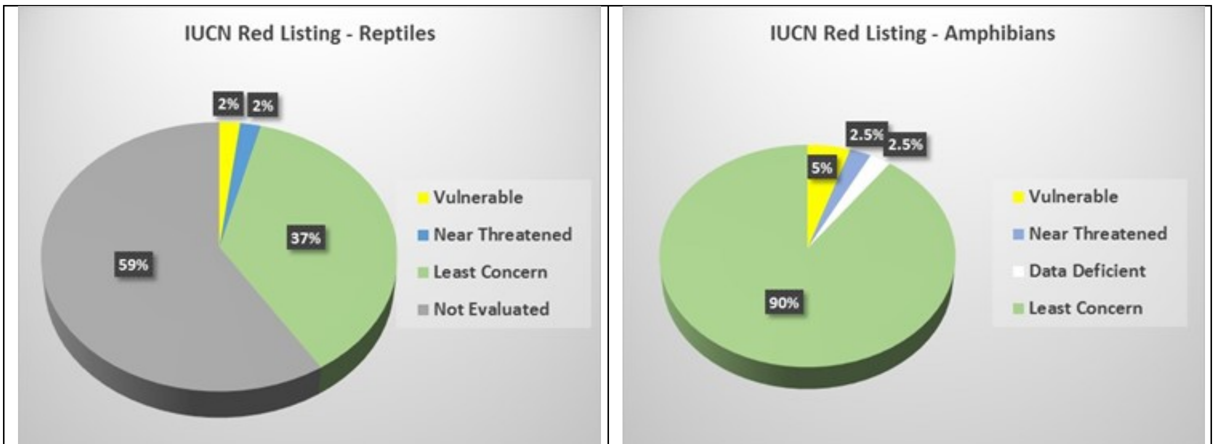
Table 9: A summary of herpetofaunal survey representativeness, with the actual species richness as sampled during the two field surveys combined with the confirmed records from other sources, compared against the total potential species richness as derived from the various literature and digital database sources.

Chelonians: Recorded richness vs potential richness	1 of 1 (100%)
Snakes: Recorded richness vs potential richness	17 of 28 (60.7%)
Lizards: Recorded richness vs potential richness	19 of 28 (67.9%)
Reptiles: Recorded richness vs potential richness	37 of 57 (64.9%)
Amphibians: Recorded richness vs potential richness	18 of 40 (45%)

In summary, the field surveys sampled about 50% of the projected reptile species richness and 35.5% of the projected amphibian species richness. Reptiles, especially snakes, are difficult to survey and several weeks are typically needed to encounter 80^{+}% of the species in a particular study area. The achievement of 50% of the expected reptile species total is thus reasonable within the limitations of a survey effort of about three weeks in duration and that was conducted within a very large and logistically challenging study area. In contrast, amphibians are generally easier to survey than reptiles and a better ratio of sampled species versus expected species is usually achieved. The low sampled amphibian tally is ascribed to the limitations of the night-time COVID curfew and the influence of below average rainfall. The contributions of confirmed records from other sources increased the sampled richness baseline values to about 65% and 45% for reptiles and amphibians respectively.

5.3. Species of conservation concern

A small proportion of the study area's herpetofaunal communities is listed as being threatened or NT, i.e. 3.5% of the reptiles and 10% of amphibians (see Figures 18a, b). None of the NE (59%) reptile species are likely candidates for any of the IUCN categories of being threatened, and these are tentatively considered to be of LC. The relatively low representation of threatened species is of convenience in the context of the proposed road-upgrading project. Only four species are deemed to be of special consideration in the context of the Project Development Area. These are Kenya Horned Viper, Lönnberg's Toad, Kinangop Puddle Frog and Silver-bladdered Reed Frog.



a) b)

Figure 18: Proportional representation of the IUCN Red Listing of the reptile (a) and amphibian (b) species that are known from or that may potentially occur within the study area.

5.4. Levels of endemism

Herpetofaunal endemism for the study area is as follow:

- **Reptiles endemic to Kenya**: 3 of 57 = about 5%.
- **Reptiles endemic to East African**: 10 of 57 = about 18%.
- **Non-endemic reptiles**: 47 of 57 = about 82%.
- **Amphibians endemic to Kenya**: 6 of 40 = about 15%.
- **Amphibians endemic to East African**: 15 of 40 = about 38%.
- **Non-endemic Amphibians**: 25 of 40 = about 62%.

5.5. Biogeographical clusters

An assessment of sub-Saharan biogeographical regions (Linder et al. 2012) is of peripheral relevance to the project. The herpetofauna of Kenya is comprised of four distinct biogeographical clusters. These are primarily Somalian for reptiles, with Sudanian and Ethiopian clusters entering peripherally along the south-western borders of Kenya (Figure 19). The situation is more complex for amphibians, with Kenyan, Somalian, Sudanian and Zambezian biogeographical clusters (Figure 20).

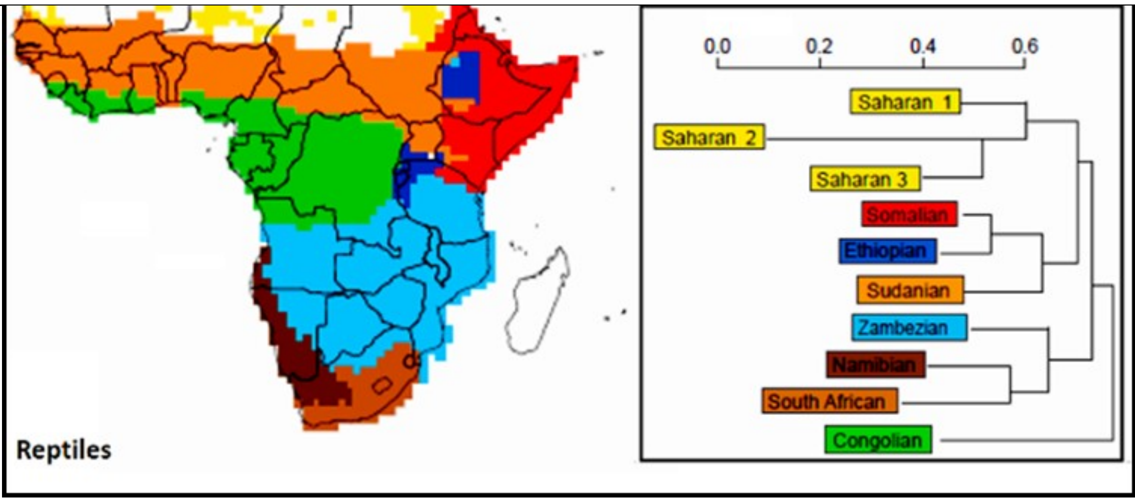


Figure 19: Sub-Saharan biogeographical regions for reptiles (Linder et al. 2012).

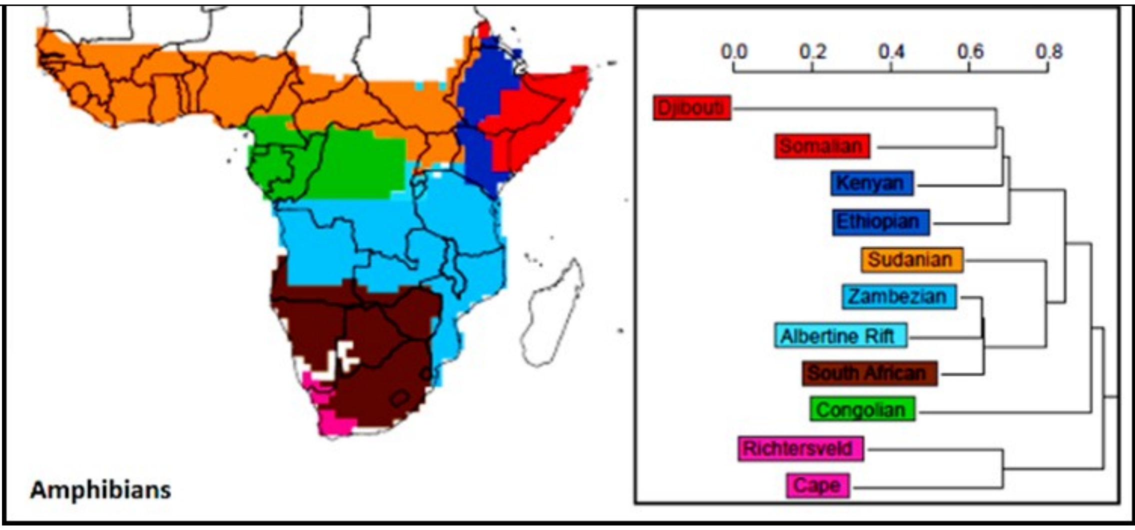


Figure 20: Sub-Saharan biogeographical regions for amphibians (Linder et al. 2012).

5.6. Sensitive and important habitats

The diversity of herpetofaunal guilds demonstrate that species differ in their preferences of or dependencies on habitat types. Greater habitat diversity provides the potential to support greater species richness. Much of the original habitat of the Regional and Local Assessment Areas has been anthropogenically transformed, but several remnant clusters of natural or semi-natural habitat still remain. These exist mainly due to some clusters having being managed as protected areas and conservancies. At a regional scale, this patchwork of natural areas provides a substantial degree of ecological resilience for the various biodiversity groups. From a herpetofaunal perspective these allow for the continued, albeit patchy, occurrence of habitat specialist species. Habitat generalist species are more likely to persist under these transformed conditions, with some species (e.g. Striped Skinks, Tropical House Geckos) seemingly flourishing in anthropogenic environments. Whereas the ecological value of large protected areas is not in dispute, the contributions of much smaller or localised habitat features within degraded conditions can be noteworthy. The following examples are of relevance to the Local Assessment Area:

- **Alien vegetation hedges**: Alien vegetation is very often unsuitable to the species that would otherwise have inhabited a particular area. However, it was noticed during the 2021 survey that hedges of various alien plant species were in fact well occupied by three chameleon species (Figure 21), especially so by High-casqued Chameleons.
- **Road-side rocky ridges**: Rocky habitat is present at a few nodes along both of the road study areas that are being assessed. Some of these rocky ridges are situated literally within the Project Development Area, i.e. within the existing Road Reserve and Project footprint. These provide habitat for rupicolous species such as agamid lizards and skinks (see Figures 22 and 23). Some of these rocky ridges are natural, whereas others are artificially stacked. Either way, they provide suitable habitat for rock-living lizards. These belts of azonal habitat is relatively uncommon within the Local Assessment Area and should therefore be flagged as sensitive nodes.
- **Road-side flooded terrain and ditches**: Endorheic wetlands such as road-side flooded terrain next to roads provide breeding habitat for a substantial variety of frogs. These artificial wetlands are in fact of greater importance as frog breeding habitat than for example streams and rivers (i.e. riverine systems). From the project's perspective, the creation of additional road-side ditches would to a certain extent promote frog abundance in a particular area. However, a degree of frog-on-road mortalities would likely be incurred in areas where wetlands are situated very close to roads. If some of the existing road-side endorheic wetlands are to be impacted during the Nairobi-Nakuru-Mau Summit Highway Project, it could be effectively mitigated in some instances by creating new artificial ditches or shallow excavations some distance from the road.

a) b)

Figure 21: Three species of chameleons were recorded from hedges in urban, peri-urban and rural settings. The most common species was the High-casqued Cameleon, with >80 observed. The specimen in Figure 21b is a Side-striped Chameleon.

a)

b)

c)

Figure 22: Species composition of agamid lizards and Striped Skinks (yellow dots) along three rocky-ridge transects, as per observations during the 2021 surveys: *Agama caudospinosa* (red dots) and *Acanthocercus gregorii* (blue dots). The first two (a & b) are along natural to partially manipulated rocky belts, whereas the third (c) is along a row of stacked rocks. Either way, these habitats are readily utilised by rupicolous lizards.

a)

b)

c)

d)

e)

Figure 23: Clusters of rocky habitat (e) are present along a few sections of the Project Development Area (PDA). These are inhabited by a few species of rupicolous lizars such as Striped Skinks, Gregory's Tree Agamas (a & b) and Elmentaita Rock Agamas (c & d). Such azonal habitat clusters are relatively scarce within the PDA and should therefore be flagged as sensitive zones.

a)

b)

c)

d)

Figure 24: Road-side flooded terrain and ditches (a – c) provide prime habitat for a variety of frog species in the study area. These endorheic wetlands can be utilised by a dozen or more species during the peak of the frog breeding season, including threatened species like Lönnberg's Toad (d; VU) that was recorded breeding here during the April 2021 survey.

6. EXPERT STATEMENT ON THE PROBABLE LEVEL OF IMPACT FROM THE ROAD

The potential negative ecological impacts of roads on herpetofauna are different for the construction and the operational phases. The existing levels of vehicular traffic on the existing roads of the Project Development Area equates to an operational phase that is currently in place. The proposed upgrading of the Nairobi-Nakuru-Mau Summit Highway will represent a construction phase, followed by a new operational phase upon completion of this project.

6.1. Construction phase

The negative impacts of the construction phase can be grouped as follow:

- **Loss of habitat**: Much of the existing road-side habitat is in a degraded state with little to no ecological value. However, several nodes exist with habitat features that are indeed of some ecological value and that are currently being utilised by reptiles and amphibians in spite of being situated immediately adjacent to a high-traffic road. These include for example road-side rocky ridges, trees, hedges, bush-clumps, rivers and streams, flooded terrain that forms seasonal wetlands (e.g. ditches and other excavations), etc. Depending on the scale of the proposed road upgrading and expansion, some of the existing road-side habitat will be transformed by the development. The loss of these road-side habitat units will impact on the existing populations of lizards, snakes and frogs at a local scale.
- **Contamination of habitat**: In addition to the loss of road-side herpetofaunal habitat, road-construction activities can potentially also contaminate terrestrial and wetland habitat. Seasonal wetlands in particular are prone to chemical pollution and siltation events. Although most of the amphibian fauna in this region are within the terrestrial guild, their tadpoles are sensitive to wetland contamination or siltation events. Likewise, aquatic pipid frogs (i.e. *Xenopus* spp.) and frogs that associate strongly with wetland fringes (e.g. *Amietia* spp.) are also at risk of chemical contamination events.
- **Direct mortalities**: Reptiles and amphibians can be killed during the earth-works activities.

6.2. Operational phase

The most relevant negative impacts of the operational phase are on-road mortalities and altering of behaviour:

- **Road mortalities**: The most severe of the negative impacts happens during the operational phase, i.e. mortalities of specimens that are killed by vehicular traffic when trying to cross roads. The intensity of these mortalities differ between faunal groups and between specific sites. Some reptiles are slow-moving (e.g. tortoises, chameleons, thread snakes) and are thus more susceptible to getting killed when crossing roads because they take longer to do so. Frog mortalities can be particularly severe in scenarios where breeding individuals make annual migrations to the wetlands and when newly metamorphosed froglets disperse away from the wetlands. The species composition of road-mortality victims differ between day and night, due to the stratification of diurnal and nocturnal species. Not much can be done to effectively mitigate herpetofaunal on road mortalities. The potential for incorporating underpasses near wetland areas must be considered where viable.
- **Road avoidance**: Intense vehicular traffic can create a deterrent that may dissuade individuals to cross a road, and thus at least partially serving as a barrier between populations on each side of the road.

In general, the overall species composition of reptiles and amphibians of the study area is not of special significance in relation of the Kenyan herpetofauna. A few localised species occur in the general region, e.g. Kinangop Dainty Frog and Irangi Puddle Frog, but these are not of direct relevance to the Project Development Area. The only four species that occur within the Project Development Area are deemed to be of special status and special consideration are the Kenya Horned Viper, Lönnberg's Toad, Kinangop Puddle Frog and Silver-bladdered Reed Frog. The most significant impact is already currently in place, i.e. road mortalities by vehicular traffic on the existing roads. The upgrading of these roads will increase vehicular traffic and will therefore also increase the severity of on-road mortalities of reptiles and amphibians. The roads will thus be more difficult to traverse safely. The significance of the increase in severity of the road upgrades is likely to be low, because the current scenario already serves as the primary cause of the on-road mortalities and thus the projected increase of traffic will add only marginally to that.

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9. APPENDIX I: Reptilia of Kenya – checklist and taxonomy

9.1. Checklist of Kenya Reptilia

The following is a checklist (Table 10) of the reptiles of Kenya, to serve as context for the Nairobi-Nakuru-Mau Summit study area. The layout of the checklist is in alphabetical order, starting firstly with the family level, then genus and species. The subfamily distinctions were not included, and thus the various genera/species of different subfamilies within a particular family may be intermixed due to the alphabetical ordering. The current IUCN Red List status is presented as per the following categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient and LC – Least Concern. Endemism is presented as Kenyan endemics (KE EN) and East African endemics (EA EN). Scoring for likelihood of occurrence within the 2 km buffered roads study area is as follow: Possible occurrence (1), probable occurrence (2) and confirmed occurrence within the 2 km road buffers of the Nairobi-Nakuru-Mau Summit Highway Project study area as per records obtained during the FFMES 2021 surveys and from other data sources (3).

Table 10: A checklist of the reptiles of Kenia.

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
TESTUDINES					
Testudinidae					
Stigmochelys pardalis	Leopard Tortoise	LC	0	0	3
Kinixys belliana	Bell's Hinged-back Tortoise	LC	0	0	0
Kinixys spekii	Speke's Hinged-back Tortoise	LC	0	0	0
Kinixys zombensis	Eastern Hinged-back Tortoise	LC	0	0	0
Malacochersus tornieri	Pancake Tortoise	CR	0	1	0
Trionychoidea					
Trionyx triunguis	Nile Soft-shelled Turtle	VU	0	0	0
Pelomedusidae					
Pelomedusa neumanni	Neumann's Marsh Terrapin	NE	0	1	0
Pelusios broadleyi	Lake Turkana Hinged Terrapin	VU	1	1	0
Pelusios castanoides	Yellow-bellied Hinged Terrapin	LC	0	0	0
Pelusios sinuatus	Serrated Hinged Terrapin	LC	0	0	0
Pelusios williamsi	Williams' Hinged Terrapin	LC	0	0	0
CROCODYLIA					
Crocodylidae					
Crocodylus niloticus	Nile Crocodile	LC	0	0	0
SQUAMATA: SAURIA					
Agamidae					
Acanthocercus annectans	Eritrean Rock Agama	NE	0	0	0
Acanthocercus gregorii	Gregory's Tree Agama	LC	0	0	3
Acanthocercus minutus	Lesser Tree Agama	LC	0	0	0
Agama armata	Tropical Spiny Agama	LC	0	0	0
Agama caudospinosa	Elementeita Rock Agama	LC	1	1	3
Agama finchi	Finch's Agama	NE	0	0	0
Agama hulbertorum	Ngong Agama	NE	1	1	0
Agama kaimosae	Kakamega Agama	LC	0	1	0
Agama lionotus	Kenya Red-headed Agama	LC	0	0	3
Agama mwanzae	Mwanza Flat-headed Agama	LC	0	1	0
Agama persimilis	Somali Painted Agama	LC	0	0	0
Agama rueppelli	Ruppell's Agama	LC	0	0	0
Agama wachirai	Wachira's Rock Agama	NE	1	1	0
Amphisbaenidae					
Geocalamus acutus	Voi Wedge-snouted Worm Lizard	NE	0	1	0

Table 10 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Chamaeleonidae					
Rieppeleon brevicaudatus	Beardless Pygmy Chameleon	LC	0	0	0
Rieppeleon kerstenii	Kenya Pygmy Chameleon	LC	0	0	0
Rhampholeon boulengeri	Boulenger's Pygmy Chameleon	LC	0	0	0
Chamaeleo dilepis	Common Flap-necked Chameleon	LC	0	0	1
Chamaeleo gracilis	Slender Chameleon	LC	0	0	0
Chamaeleo laevigatus	Smooth Chameleon	LC	0	0	0
Kinyongia asheorum	Mount Nyiro Bearded Chameleon	**NT**	1	1	0
Kinyongia boehmei	Taita Hills Blade-horned Chameleon	**NT**	1	1	0
Kinyongia excubitor	Mount Kenya Dwarf Chameleon	**VU**	1	1	0
Kinyongia tavetana	Mnt Kilimanjaro Two-horned Chameleon	**NT**	0	1	0
Kinyongia tenuis	Usambara Soft-horned Chameleon	**EN**	0	1	0
Trioceros bitaeniatus	Side-striped Chameleon	LC	0	0	3
Trioceros ellioti	Montane Side-striped Chameleon	LC	0	0	0
Trioceros hoehnelii	High-casqued Chameleon	LC	0	1	3
Trioceros jacksonii	Jackson's Chameleon	LC	0	1	3
Trioceros kinangopensis	Aberdare Mountains Dwarf Chameleon	**NT**	1	1	0
Trioceros marsabitensis	Mount Marsabit Chameleon	**NT**	1	1	0
Trioceros narraioca	Mount Kulal Stump-nosed Chameleon	**NT**	1	1	0
Trioceros ntunte	Mount Nyiru Chameleon	DD	1	1	0
Trioceros nyirit	Mtelo Massif Chameleon	LC	1	1	0
Trioceros schubotzi	Mount Kenya Side-striped Chameleon	**NT**	1	1	0
Cordylidae					
Chamaesaura tenuior	East African Highland Grass Lizard	NE	0	0	2
Cordylus beraduccii	Maasai Girdled Lizard	NE	0	1	0
Cordylus tropidosternum	Tropical Girdled Lizard	NE	0	0	0
Eublepharidae					
Holodactylus africanus	Somali-Maasai Clawed Gecko	LC	0	0	0
Gekkonidae					
Chondrodactylus turneri	Turner's Gecko	LC	0	0	0
Cnemaspis africana	Usambara Forest Gecko	LC	0	1	0
Cnemaspis dickersonae	Dickerson's Forest Gecko	NE	0	0	0
Cnemaspis elgonensis	Elgon Forest Gecko	**VU**	0	0	0
Hemidactylus angulatus	East African House Gecko	NE	0	0	2
Hemidactylus barbierii	Barbieri's Turkana Gecko	DD	1	1	0
Hemidactylus barbouri	Barbour's Gecko	LC	0	1	0
Hemidactylus bavazzanoi	Somali Banded Gecko	DD	0	0	0
Hemidactylus funaiolii	Archer's Post Gecko	DD	0	0	0
Hemidactylus mabouia	Tropical House Gecko	LC	0	0	3
Hemidactylus macropholis	Boulenger's Gecko	LC	0	0	0
Hemidactylus modestus	Tana River Gecko	DD	1	1	0
Hemidactylus mrimaensis	Kaya Gecko	NE	1	1	0
Hemidactylus platycephalus	Tree Gecko	NE	0	0	0
Hemidactylus robustus	Somali Plain Gecko	LC	0	0	0
Hemidactylus ruspolii	Prince Ruspoli's Gecko	LC	0	0	0
Hemidactylus squamulatus	Nyika Gecko	LC	0	1	3
Hemidactylus tropidolepis	Ogaden Gecko	LC	0	0	0

Table 10 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Homopholis fasciata	Banded Velvet Gecko	LC	0	0	0
Lygodactylus angolensis	Angolen Dwarf Gecko	NE	0	0	2
Lygodactylus angularis	Angulate Dwarf Gecko	NE	0	0	0
Lygodactylus capensis	Cape Dwarf Gecko	NE	0	0	3
Lygodactylus grandisonae	Bunty's Dwarf Gecko	DD	0	1	0
Lygodactylus gutturalis	Chevron-throated Dwarf Gecko	NE	1	0	0
Lygodactylus keniensis	Kenya Dwarf Gecko	LC	0	0	3
Lygodactylus kimhowelli	Kim Howell's Dwarf Gecko	NE	0	1	0
Lygodactylus laterimaculatus	Side-spotted Dwarf Gecko	LC	0	1	0
Lygodactylus manni	Mann's Dwarf Gecko	LC	0	1	1
Lygodactylus mombasicus	White-headed Dwarf Gecko	LC	0	1	0
Lygodactylus picturatus	Yellow-headed Dwarf Gecko	LC	0	0	0
Lygodactylus scheffleri	Scheffler's Dwarf-Gecko	DD	0	1	0
Lygodactylus scorteccii	Scortecci's Dwarf Gecko	NE	1	1	0
Lygodactylus somalicus	Somali Dwarf Gecko	NE	0	0	0
Lygodactylus tsavoensis	Tsavo Dwarf Gecko	NE	1	1	0
Lygodactylus wojnowskii	Mount Kenya Dwarf Gecko	NE	1	1	0
Phelsuma dubia	Pemba Day Gecko	LC	0	1	0
Stenodactylus sthenodactylus	Elegant Gecko	LC	0	0	0
Gerrhosauridae					
Broadleysaurus major	Great Plated Lizard	NE	0	0	0
Gerrhosaurus flavigularis	Yellow-throated Plated Lizard	NE	0	0	3
Gerrhosaurus nigrolineatus	Black-lined Plated Lizard	NE	0	0	2
Lacertidae					
Adolfus africanus	Multi-scaled Forest Lizard	LC	0	0	0
Adolfus alleni	Mount Kenya Alpine Meadow Lizard	**NT**	1	1	0
Adolfus jacksoni	Jackson's Forest Lizard	NE	0	0	3
Adolfus kibonotensis	Kilimanjaro Forest Lizard	NE	0	1	1
Adolfus masavaensis	Western Alpine Meadow Lizard	**NT**	0	1	0
Adolfus mathewsensis	Mathew's Forest Lizard	NE	1	1	0
Gastropholis prasina	Green Keel-bellied Lizard	**NT**	0	1	0
Gastropholis vittata	Stripped Keel-bellied Lizard	NE	0	0	0
Heliobolus neumanni	Neumann's Sand Lizard	DD	0	0	0
Heliobolus spekii	Speke's Sand Lizard	NE	0	0	0
Holaspis laevis	Eastern Blue-tailed Gliding Lizard	NE	0	0	0
Latastia caeruleopunctata	Parker's Long-tailed Lizard	NE	0	0	0
Latastia longicaudata	Southern Long-tailed Lizard	LC	0	0	0
Nucras boulengeri	Boulenger's Scrub Lizard	NE	0	0	3
Philochortus rudolfensis	Turkana Shield-backed Ground Lizard	NE	0	0	0
Pseuderemias smithii	Smith's Sand Lizard	NE	0	0	0
Scincidae					
Acontias percivali	Percival's Leggless Skink	LC	0	1	0
Chalcides bottegi	Occelated Skink	LC	0	0	0
Cryptoblepharus africanus	Coral Rag Skink	LC	0	0	0
Eumecia anchietae	Western Serpentiform Skink	LC	0	1	0
Feylinia currori	Western Forest Skink	LC	0	0	0

Table 10 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Leptosiaphos kilimensis	Kilimanjaro Five-toed Skink	NE	0	0	2
Leptosiaphos meleagris	Blue-tailed Five-toed Skink	VU	0	1	0
Melanoseps pygmaeus	Pygmy Limbless Skink	NE	0	1	0
Mochlus hinkeli	Hinkel's Red-flanked Skink	NE	0	0	0
Mochlus mabuiiformis	Mabuya-like Writhing Skink	DD	1	1	0
Mochlus pembanus	Pemba Island Writhing Skink	LC	0	1	0
Mochlus somalicus	Somali Writhing Skink	LC	0	0	0
Mochlus sundevallii	Sundevall's Writhing Skink	LC	0	0	3
Mochlus tanae	Tana River Writhing Skink	LC	0	1	0
Panaspis massaiensis	Maasai Snake-eyed Skink	NE	0	1	3
Panaspis tsavoensis	Tsavo Snake-eyed Skink	NE	0	1	0
Trachylepis bayonii	Bayon's Skink	DD	0	1	0
Trachylepis brevicollis	Short-necked Skink	LC	0	0	0
Trachylepis dichroma	Bi-coloured Skink	LC	0	0	0
Trachylepis irregularis	Alpine Meadow Skink	**NT**	0	1	2
Trachylepis maculilabris	Speckle-lipped Skink	NE	0	0	0
Trachylepis margaritifera	Rainbow Skink	LC	0	0	0
Trachylepis megalura	Long-tailed Skink	LC	0	0	3
Trachylepis planifrons	Tree Skink	NE	0	0	0
Trachylepis quinquetaeniata	Five-lined Skink	LC	0	0	0
Trachylepis striata	Striped Skink	LC	0	0	3
Trachylepis varia	Variable Skink	LC	0	0	3
Sphaerodactylidae					
Pristurus crucifer	Cross-marked Sand Gecko	LC	0	0	0
Varanidae					
Varanus albigularis	White-throated Savanna Monitor	NE	0	0	0
Varanus niloticus	Nile Monitor	NE	0	0	3
SQUAMATA: SERPENTES					
Atractaspididae					
Amblyodipsas polylepis	Common Purple-glossed Snake	NE	0	0	0
Amblyodipsas teitana	Taita Hills Purple-glossed Snake	DD	1	1	0
Amblyodipsas unicolor	Western Purple-glossed Snake	NE	0	0	0
Aparallactus guentheri	Black Centipede-eater	NE	0	0	0
Aparallactus jacksonii	Jackson's Centipede-eater	NE	0	0	3
Aparallactus turneri	Malindi Centipede-eater	LC	1	1	0
Atractaspis bibronii	Bibron's Stiletto Snake	NE	0	0	0
Atractaspis engdahli	Engdahl's Stiletto Snake	NE	0	0	0
Atractaspis fallax	Eastern Small-scaled Stiletto Snake	LC	0	0	0
Atractaspis irregularis	Variable Stiletto Snake	LC	0	0	2
Polemon christyi	Christy's Snake-eater	NE	0	0	0
Boidae					
Eryx colubrinus	Kenya Sand Boa	NE	0	0	0
Colubridae					
Crotaphopeltis braestrupi	Tana Herald Snake	NE	1	1	0
Crotaphopeltis degeni	Yellow-flanked Snake	NE	0	0	0
Crotaphopeltis hotamboeia	White-lipped Snake	NE	0	0	3

Table 10 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Dasypeltis atra	Montane Egg-eater	NE	0	0	2
Dasypeltis confusa	Confusing Egg-eater	NE	0	0	0
Dasypeltis medici	Rufous Egg-eater	NE	0	0	0
Dasypeltis scabra	Rhombic Egg-eater	LC	0	0	3
Dipsadoboa flavida	Cross-barred Tree Snake	NE	0	0	0
Dispholidus typus	Boomslang	NE	0	0	3
Hapsidophrys lineatus	Black-lined Green Snake	NE	0	0	0
Meizodon krameri	Tana Delta Smooth Snake	DD	1	1	0
Meizodon plumbiceps	Black-headed Smooth Snake	LC	0	0	0
Meizodon regularis	Eastern Crowned Snake	NE	0	0	0
Meizodon semiornatus	Semi-ornate Snake	NE	0	0	2
Philothamnus battersbyi	Battersby's Green Snake	NE	0	0	3
Philothamnus carinatus	Thirteen-scaled Green Snake	NE	0	0	0
Philothamnus heterolepidotus	Slender Green Snake	NE	0	0	0
Philothamnus hoplogaster	South-Eastern Green Snake	NE	0	0	0
Philothamnus nitidus	Loveridge's Green Snake	NE	0	0	0
Philothamnus punctatus	Speckled Green Snake	NE	0	0	0
Philothamnus semivariegatus	Spotted Bush Snake	NE	0	0	0
Platyceps brevis	Smith's Racer	NE	0	0	0
Platyceps florulentus	Flowered Racer	LC	0	0	0
Rhamnophis aethiopissa	Large-eyed Green Tree Snake	NE	0	0	0
Scaphiophis albopunctatus	Hook-nosed Snake	NE	0	0	0
Scaphiophis raffreyi	Ethiopian Hook-nosed Snake	NE	0	0	0
Telescopus dhara	Large-eyed Snake	NE	0	0	0
Telescopus obtusus	Egyptian Cat Snake	LC	0	0	0
Telescopus semiannulatus	Tiger Snake	NE	0	0	0
Thelotornis mossambicanus	Eastern Vine Snake	NE	0	0	0
Thelotornis usambaricus	Usambara Vine Snake	**VU**	0	1	0
Thrasops jacksonii	Jackson's Tree Snake	NE	0	0	0
Thrasops schmidti	Meru Tree Snake	**EN**	0	0	0
Toxicodryas adamanteus	Diamonds Tree Snake	NE	0	0	0
Toxicodryas vexator	Stalker Tree Snake	NE	0	0	0
Elapidae					
Elapsoidea loveridgei	East African Garter Snake	NE	0	0	2
Elapsoidea nigra	Usambara Garter Snake	**EN**	0	1	0
Naja haje	Egyptian Cobra	NE	0	0	2
Naja subfulva	Brown Forest Cobra	NE	0	0	3
Naja nigricollis	Black-necked Spitting Cobra	NE	0	0	3
Naja ashei	Ashe's Spitting Cobra	NE	0	0	0
Naja pallida	Red Spitting Cobra	NE	0	0	0
Pseudohaje goldii	Gold's Tree Cobra	NE	0	0	0
Dendroaspis angusticeps	Green Mamba	NE	0	0	0
Dendroaspis jamesoni	Jameson's Mamba	NE	0	0	0
Dendroaspis polylepis	Black Mamba	LC	0	0	1
Grayiidae					
Grayia smithii	Smyth's Water Snake	NE	0	0	0
Grayia tholloni	Thollon's Water Snake	NE	0	0	0

Table 10 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Lamprophiidae					
Boaedon fuliginosus	African House Snake	NE	0	0	3
Boaedon olivaceus	Olive House Snake	NE	0	0	0
Gracililima nyassae	Black File Snake	LC	0	0	0
Hormonotus modestus	Yellow Forest Snake	NE	0	0	0
Limaformosa chanleri	Chanler's File Snake	NE	0	0	0
Limaformosa savorgnani	Congo File Snake	NE	0	0	0
Lycophidion capense	Cape Wolf Snake	NE	0	0	3
Lycophidion depressirostre	Flat-snouted Wolf Snake	NE	0	0	0
Lycophidion meleagre	Speckled Wold Snake	NE	0	1	0
Lycophidion ornatum	Forest Wolf Snake	LC	0	0	2
Lycophidion taylori	Taylor's Wolf Snake	NE	0	0	0
Micrelaps bicoloratus	Two-coloured Snake	LC	0	1	0
Micrelaps vaillanti	Guinea-fowl Snake	LC	0	0	0
Leptotyphlopidae					
Epacrophis boulengeri	Lamu Thread Snake	DD	1	1	0
Epacrophis drewesi	Drewe's Thread Snake	DD	1	1	0
Leptotyphlops aethiopicus	Ethiopian Thread Snake	DD	0	1	0
Leptotyphlops howelli	Kim Howell's Thread Snake	DD	0	1	0
Leptotyphlops keniensis	Mount Kenya Thread Snake	DD	0	0	0
Leptotyphlops macrops	Large-eyed Thread Snake	LC	0	1	0
Leptotyphlops merkeri	Merker's Thread Snake	LC	0	0	3
Leptotyphlops nigroterminus	Black-tipped Thread Snake	NE	0	1	0
Leptotyphlops pitmani	Pitman's Thread Snake	NE	0	0	0
Myriopholis braccianii	Scortecci's Thread Snake	LC	0	1	0
Myriopholis macrorhyncha	Hook-snouted Thread Snake	NE	0	0	0
Myriopholis parkeri	Parker's Thread Snake	NE	0	0	0
Myriopholis tanae	Tana Delta Thread Snake	DD	0	0	0
Natricidae					
Natriciteres olivacea	Olive Marsh Snake	LC	0	0	0
Prosymnidae					
Prosymna ambigua	Angolan Shovel-snout	LC	0	0	0
Prosymna ruspolii	Prince Ruspoli's Shovel-snout	NE	0	0	0
Prosymna stuhlmanni	East African Shovel-snout	NE	0	0	0
Psammophiidae					
Hemirhagerrhis hildebrandtii	Kenyan Bark Snake	LC	0	0	0
Hemirhagerrhis kelleri	Striped Bark Snake	NE	0	0	0
Hemirhagerrhis nototaenia	South-Eastern Bark Snake	NE	0	0	0
Psammophis biseriatus	Link-marked Sand Snake	NE	0	0	0
Psammophis lineatus	Lined Olympic Snake	NE	0	0	0
Psammophis mossambicus	Olive Sand Snake	NE	0	0	3
Psammophis orientalis	Eastern Stripe-Bellied Sand Snake	NE	0	0	0
Psammophis pulcher	Beautiful Sand Snake	NE	0	0	0
Psammophis punctulatus	Speckled Sand Snake	NE	0	0	0
Psammophis rukwae	Lake Rukwa Sand Snake	NE	0	0	0
Psammophis sudanensis	Northern Stripe-bellied Sand Snake	NE	0	0	3
Psammophis tanganicus	Tanganyika Sand Snake	NE	0	0	0
Psammophylax multisquamis	Kenyan Striped Skaapsteker	NE	0	0	3

Table 10 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Rhamphiophis rostratus	Rufous Beaked Snake	NE	0	0	0
Rhamphiophis rubropunctatus	Red-spotted Beaked Snake	LC	0	0	0
Pseudaspididae					
Pseudaspis cana	Mole Snake	NE	0	0	3
Pseudoxyrhophiidae					
Duberria atriventris	Dusky-bellied Slug-eater	NE	0	1	3
Pythonidae					
Python natalensis	Southern African Rock Python	NE	0	0	3
Python sebae	Central African Rock Python	NE	0	0	0
Typhlopidae					
Afrotyphlops angolensis	Angola Blind Snake	NE	0	0	1
Afrotyphlops brevis	Angle-snouted Blind Snake	NE	0	0	0
Afrotyphlops calabresii	Southern Wedge-snouted Blind Snake	NE	0	0	0
Afrotyphlops kaimosae	Kakamega Blind Snake	DD	1	1	0
Afrotyphlops lineolatus	Lineolate Blind Snake	NE	0	0	3
Afrotyphlops mucruso	Zambezi Giant Blind Snake	NE	0	0	0
Afrotyphlops nanus	Kenyan Dwarf Blind Snake	DD	1	1	0
Letheobia lumbriciformis	Worm-like Gracile Blind Snake	LC	0	1	0
Letheobia mbeerensis	Mbeere Gracile Blind Snake	NE	1	1	0
Letheobia swahilica	Swahili Gracile Blind Snake	LC	0	1	0
Rhinotyphlops ataeniatus	Somali Blind Snake	NE	0	0	0
Rhinotyphlops unitaeniatus	Yellow Striped Blind Snake	NE	0	0	0
Viperidae					
Atheris desaixi	Mount Kenya Bush Viper	**EN**	1	1	0
Atheris hispida	Rough-scaled Bush Viper	NE	0	0	0
Atheris squamigera	Green Bush Viper	NE	0	0	0
Bitis arietans	Puff Adder	NE	0	0	3
Bitis gabonica	Gaboon Adder	NE	0	0	0
Bitis nascornis	Rhinoceros Viper	LC	0	0	0
Bitis worthingtoni	Kenya Horned Viper	**VU**	1	1	3
Causus defilippii	Snouted Night adder	NE	0	0	0
Causus lichtensteinii	Forest Night Adder	NE	0	0	0
Causus resimus	Velvety-green Night Adder	NE	0	0	0
Causus rhombeatus	Rhombic Night adder	NE	0	0	3
Echis pyramidum	North-East African Carpet Viper	LC	0	0	0
Montatheris hindii	Kenya Montane Viper	**NT**	1	1	0
TOTALS			**35/271**	**79/271**	**57/271**

9.2. Taxonomy of Kenya Reptilia

The following taxonomic remarks are in reference to the Kenya country reptile species checklist (Table 10). These serve to point out recent taxonomic changes and species identification uncertainties.

Acanthocercus gregorii: Much of the tree agama records from the digital data sets and even some of the fairly recent primary literature (e.g. Spawls et al. 2018) refer to A*canthocercus atricollis* from the study area. However, the revised name for specimens from this region is *Acanthocercus gregorii* as per Wagner et al. (2018).

Agama caudospinosa* vs *Agama lionotus: In addition to Gregory's Tree Agama (above), another two similar-looking species of agamas occur in the study area. We observed 74 specimens of the genus *Agama* during the two field surveys (Figure 25). These were tentatively identified as *Agama caudospinosa*, a Kenyan endemic which is fairly common in the Elmenteita and Naivasha regions. However, at Lake Nakuru which is about 12 km to the north-west of the Lake Elmeneita, apparently only *Agama lionotus* occurs. This is based on 47 iNaturalist records. The records of these two species were plotted on a map (Figure 26) to illustrate this seemingly abrupt species turn-over. Additional fieldwork would be needed to determine contact and/or overlap areas in the distributions of these two species, but for the purpose of this report the demographics of the two species are considered to be approximately as plotted on our map.

Figure 25: A collection of *Agama caudospinosa* observations that were recorded at various sampling points during the February 2021 survey.

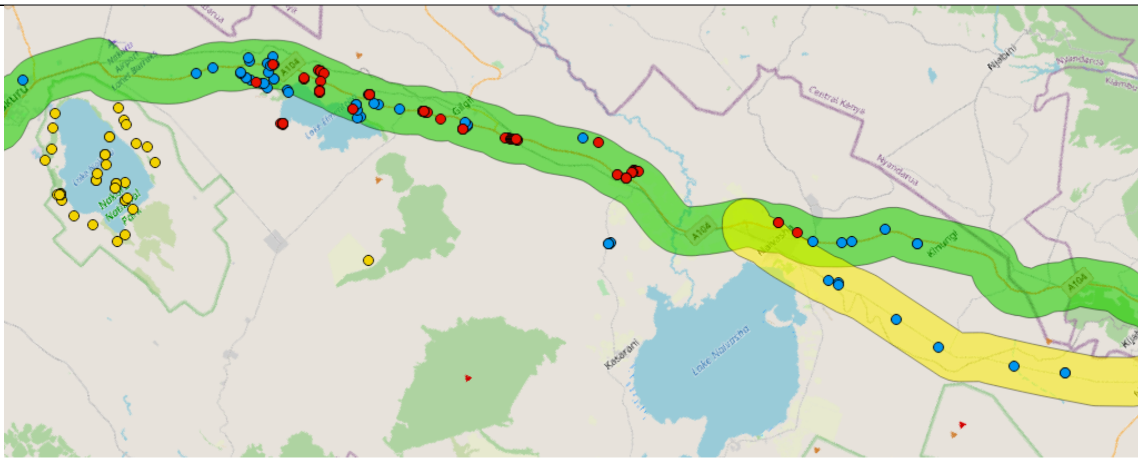


Figure 26: Some uncertainty exists about the identifications of agamas in the Nakuru/Naivasha regions. We tentatively interpreted the situation to be that the population around Lake Nakuru is assigned to *Agama lionotus* (yellow dots), whereas *Agama caudospinosa* (red dots) is associated with the Lake Elmenteita and Naivasha regions. The blue dots reflect *Acanthocercus gregorii* observations during the 2021 surveys.

Adolfus jacksoni* vs *Adolfus kibonotensis: A recent revision of *Adolfus jacksoni* in the highlands of East Africa concluded that *A. kibonotensis* is a valid species and it was revived from synonymy with *A. jacksoni* (Greenbaum et al. 2018). According to this assessment, *A. jacksoni* occurs on the western side of the Kenyan Rift, with *A. kibonotensis* occurring from the central Kenyan highlands to northern Tanzania on the eastern side of the Kenyan Rift. Based on this assessment, the records within the study area are presumed to be *A. jacksoni*.

Duberria atriventris: This taxon is currently a subspecies of *Duberria lutrix*, but a recent study (not yet published) has elevated it to a full species.

Python natalensis* vs *Python sebae: Identification of pythons from the study area is problematic due to the morphological similarities between the two large African python species. We tentative follow the python distribution projections of Spawls et al. (2018), and therefore assume *Python natalensis* to be the relevant taxon for the study area. At the time of writing this report, this is in conflict with the iNaturalist identifications of pythons from that region.

10. APPENDIX II: Amphibia of Kenya – checklist and taxonomy

10.1. Checklist of Kenya Amphibia

The following is a checklist (Table 11) of the amphibians of Kenya, to serve as context for the Nairobi-Nakuru-Mau Summit study area. The layout of the checklist is in alphabetical order, starting firstly with the family level, then genus and species. The subfamily distinctions were not included, and thus the various genera/species of different subfamilies within a particular family may be intermixed due to the alphabetical ordering. The current IUCN Red List status is presented as per the following categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, DD – Data Deficient and LC – Least Concern. Endemism is presented as Kenyan endemics (KE EN) and East African endemics (EA EN). Scoring for likelihood of occurrence within the 2 km buffered roads study area is as follow: Possible occurrence (1), probable occurrence (2) and confirmed occurrence within the 2 km road buffers of the Nairobi-Nakuru-Mau Summit Highway Project study area as per records obtained during the FFMES 2021 surveys and from other data sources (3).

Table 11: A checklist of the amphibians of Kenia.

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
ANURA					
Arthroleptidae					
Arthroleptis stenodactylus	Common Squeaker	LC	0	0	0
Arthroleptis xenodactyloides	Dwarf Squeaker	LC	0	0	0
Leptopelis argenteus	Silvery Tree Frog	LC	0	0	0
Leptopelis bocagii	Bocage's Tree frog	LC	0	0	2
Leptopelis concolor	Witu Tree Frog	LC	0	1	0
Leptopelis flavomaculatus	Yellow-spotted Tree Frog	LC	0	1	0
Leptopelis grandiceps	Large-headed Forest Tree Frog	**VU**	0	1	0
Leptopelis mackayi	Mackay's Forest Tree Frog	**VU**	1	1	0
Brevicipitidae					
Callulina dawida	Taita Hills Warty Frog	**CR**	1	1	0
Callulina kreffti	Krefft's Warty Frog	LC	0	1	0
Bufonidae					
Mertensophryne lonnbergi	Lönnberg's Toad	**VU**	1	1	3
Mertensophryne micranotis	Woodland Toad	LC	0	1	0
Mertensophryne mocquardi	Mocquard's Toad	DD	1	1	2
Mertensophryne nairobiensis	Niarobi Toad	DD	1	1	0
Mertensophryne taitana	TaitaHills Toad	LC	0	0	0
Poyntonophrynus lughensis	Lugh Pygmy Toad	LC	0	0	0
Poyntonophrynus parkeri	Parker's Pygmy Toad	LC	0	1	0
Schismaderma carens	Red Toad	LC	0	0	0
Sclerophrys garmani	Garman's Toad	LC	0	0	3
Sclerophrys gutturalis	Guttural Toad	LC	0	0	2
Sclerophrys kerinyagae	Kerinyaga Toad	LC	0	1	3
Sclerophrys kisoloensis	Kisolo Toad	LC	0	1	2
Sclerophrys pusilla	Flat-backed Toad	LC	0	0	1
Sclerophrys regularis	Common Toad	LC	0	0	1
Sclerophrys steindachneri	Steindachner's Toad	LC	0	0	0
Sclerophrys turkanae	Lake Turkana Toad	DD	1	1	0
Sclerophrys xeros	Subsaharan Toad	LC	0	0	1
Dicroglossidae: Dicroglossinae					
Hoplobatrachus occipitalis	African Groove-crowned Frog	LC	0	0	2
Hemisotidae					
Hemisus marmoratus	Marbled Snout-burrower	LC	0	0	3

Table 11 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Hyperoliidae					
Afrixalus delicatus	Delicate Leaf-folding Frog	LC	0	0	0
Afrixalus fornasini	Fornasini's Leaf-folding Frog	LC	0	0	0
Afrixalus osorioi	Osorio's Leaf-folding Frog	LC	0	0	0
Afrixalus quadrivittatus	Four-lined Leaf-folding Frog	LC	0	0	0
Afrixalus septentrionalis	Northern Leaf-folding Frog	LC	0	0	0
Afrixalus sylvaticus	Forest Leaf-folding Frog	**VU**	0	0	0
Hylambates maculatus	Eastern Wot-Wot	LC	0	0	0
Hyperolius argus	Argus Reed Frog	LC	0	0	0
Hyperolius balfouri	Balfour's Reed Frog	LC	0	0	0
Hyperolius cinnamomeoventris	Cinnamon-bellied Reed Frog	LC	0	0	0
Hyperolius cystocandicans	Silver-bladdered Reed Frog	**NT**	1	1	3
Hyperolius glandicolor	Taita Reed Frog Reed Frog	LC	0	0	3
Hyperolius howelli	Howell's Long Reed Frog	LC	0	1	0
Hyperolius kivuensis	Kivu Reed Frog	LC	0	0	0
Hyperolius lateralis	Side-striped Reed Frog	LC	0	0	0
Hyperolius mariae	Maria's Reed Frog	LC	0	0	0
Hyperolius microps	Sharp-headed Reed Frog	DD	0	0	0
Hyperolius montanus	Mountain Reed Frog	LC	1	1	2
Hyperolius parkeri	Parker's Reed Frog	LC	0	0	0
Hyperolius pusillus	Water-lily Reed Frog	LC	0	0	1
Hyperolius rubrovermiculatus	Red-lined Reed Frog	**EN**	0	1	0
Hyperolius sheldricki	Sheldrick's Reed Frog	LC	1	1	0
Hyperolius substriatus	Mainland Reed Frog	LC	0	0	0
Hyperolius tuberilinguis	Tinker Reed Frog	LC	0	0	0
Hyperolius viridiflavus	Common Reed Frog	LC	0	0	3
Kassina maculifer	Northern Running Frog	LC	0	0	0
Kassina senegalensis	Senegal Running Frog	LC	0	0	3
Kassina somalica	Somali Running Frog	LC	0	0	0
Microhylidae					
Phrynomantis bifasciatus	Banded Rubber Frog	LC	0	0	1
Phrynomantis somalicus	Somali Rubber Frog	LC	0	1	0
Petropedetidae					
Arthroleptides dutoiti	Mount Elgon Torrent Frog	**CR**	0	1	0
Phrynobatrachidae					
Phrynobatrachus acridoides	East African Puddle Frog	LC	0	0	1
Phrynobatrachus bullans	Bubbling Puddle Frog	LC	0	1	0
Phrynobatrachus graueri	Graure's Puddle Frog	LC	1	0	0
Phrynobatrachus irangi	Irangi Puddle Frog	**EN**	1	1	0
Phrynobatrachus kakamikro	Kakamega Puddle Frog	DD	1	1	0
Phrynobatrachus keniensis	Kenya Puddle Frog	LC	1	1	3
Phrynobatrachus kinangopensis	Kinangop Puddle Frog	**VU**	1	1	1
Phrynobatrachus mababiensis	Mababe Puddle Frog	LC	0	0	1
Phrynobatrachus natalensis	Natal Puddle Frog	LC	0	0	2
Phrynobatrachus pallidus	Pale Puddle Frog	LC	0	1	0
Phrynobatrachus scheffleri	Scheffler's Puddle Frog	LC	0	1	2
Phrynobatrachus ungujae	Unguja Puddle Frog	**EN**	1	1	0

Table 11 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Pipidae					
Xenopus borealis	Northern Clawed Frog	LC	0	1	3
Xenopus clivii	Clivi's Clawed Frog	LC	0	1	0
Xenopus muelleri	Müller's Clawed Toad	LC	0	0	0
Xenopus victorianus	Mwanza Frog	LC	0	1	2
Ptychadenidae					
Hildebrandtia macrotympanum	Northern Ornate Frog	LC	0	1	0
Hildebrandtia ornata	African Ornate Frog	LC	0	0	1
Ptychadena anchietae	Plain Grass Frog	LC	0	0	3
Ptychadena mahnerti	Mahnert's Ridged Frog	LC	0	1	3
Ptychadena mossambica	Mozambique Grass Frog	LC	0	0	0
Ptychadena nilotica	Nile Grass Frog	LC	0	0	3
Ptychadena oxyrhynchus	Sharp-nosed Grass Frog	LC	0	0	1
Ptychadena porosissima	Striped Grass Frog	LC	0	0	1
Ptychadena schillukorum	Schilluk Grass Frog	LC	0	0	1
Ptychadena taenioscelis	Southern Dwarf Grass Frog	LC	0	0	0
Pyxicephalidae					
Amietia nutti	Nutt's River Frog	LC	0	0	3
Amietia tenuoplicata	Amani River Frog	LC	0	1	0
Amietia wittei	De Witte's River Frog	LC	0	1	3
Cacosternum kinangopensis	Kinangop Dainty Frog	LC	1	1	1
Cacosternum plimptoni	Plimpton's Dainty Frog	LC	0	1	3
Pyxicephalus adspersus	Giant Bull Frog	LC	0	0	0
Pyxicephalus angusticeps	Parry's Bull Frog	LC	0	0	0
Pyxicephalus edulis	Lesser Bull Frog	LC	0	0	0
Tomopterna cryptotis	Cryptic Sand Frog	LC	0	0	3
Tomopterna gallmanni	Gallmann's Sand Frog	LC	1	1	0
Tomopterna luganga	Red Sand Frog	LC	0	0	0
Tomopterna marmorata	Russet-backed Sand Frog	LC	0	0	2
Tomopterna monticola	Maasai Sand Frog	NE	1	1	0
Tomopterna tandyi	Tandy's Sand Frog	LC	0	0	1
Tomopterna wambensis	Wamba Sand Frog	LC	0	1	0
Ranidae					
Amnirana albolabris	Forest White-lipped Frog	LC	0	0	0
Amnirana galamensis	Galam White-lipped Frog	LC	0	0	0
Rhacophoridae: Rhacophorinae					
Chiromantis kelleri	Keller's Foam Nest Frog	LC	0	1	0
Chiromantis petersii	Peter's Foam Nest Frog	LC	0	1	1
Chiromantis xerampelina	Grey Foam Nest Frog	LC	0	0	0
GYMNOPHIONA					
Dermophiidae					
Schistometopum gregorii	Witu Caecilian	LC	0	1	0

Table 11 (continued)

Scientific name	Common name	IUCN	KE EN	EA EN	2 km
Herpelidae					
Boulengerula changamwensis	Changamwe Caecilian	**EN**	0	0	0
Boulengerula denhardti	Denhardt's Caecilian	DD	1	1	0
Boulengerula niedeni	Sagalla Caecilian	DD	1	1	0
Boulengerula spawlsi	Spawlls Caecilian	NE	1	1	0
Boulengerula taitana	Taita Caecilian	**EN**	1	1	0
Scolecomorphidae					
Scolecomorphus vittatus	Ribbon Caecilian	LC	0	1	0
TOTALS			**22/113**	**50/113**	**40/113**

10.2. Taxonomy of Kenya Amphibia

Several taxonomic considerations are applicable to the Kenya Amphibia checklist (Table 11), and these are briefly discussed in this section. Likewise, some of the species identification uncertainties will be highlighted here.

Hemisus guineensis: Although listed by some sources as a species that occurs in Kenya, it was omitted from this checklist based on Spawls et al. (2019).

***Hyperolius viridiflavus* complex**: Two subspecies of the *Hyperolius viridiflavus* complex were recorded during the Nairobi-Nakuru-Mau Summit Highway Project surveys, i.e. the nominate form *H. v. viridiflavus* (Figure 27a) and *H. v. ferniquei* (Figure 27b). This is taxonomically speaking the most problematic or challenging amphibian species complex in Africa, and it is beyond the scope of this investigation to make definitive statements about the taxonomy of these frogs within the study area. It is sufficient for the purpose of this project to state the presence of at least two subspecies of this common and widespread species was confirmed from the study area. Although some workers consider *H. glandicolor* as part of *H. viridiflavus* (Portik et al. 2019), as a synonym of *H. viridiflavus* (Channing & Rödel 2019), or as a subspecies of *H. viridiflavus* (Spawls et al. 2019), Frost (2021) still lists treat *glandicolor* as a valid species. We tentatively regard the *glandicolor* specimens that were recorded during our surveys as a valid species and have retained it on the amphibian checklists.

a) b)

Figure 27: At least two subspecies of the *Hyperolius viridiflavus* complex occur within the Nairobi-Nakuru-Mau Summit Highway Project study area, i.e. the nominate form *H. v. viridiflavus* (a) and *H. v. ferniquei* (b).

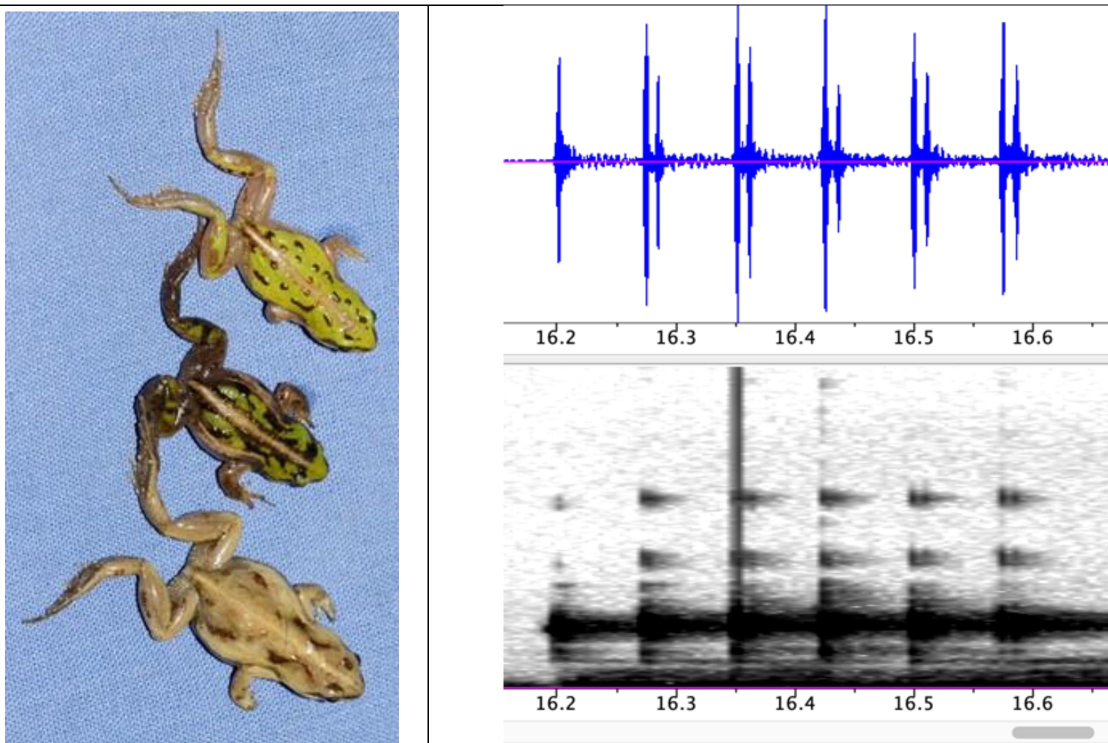
***Phrynobatrachus* spp**: Species of puddle frogs can be challenging to identify. The 2021 field study was hampered by COVID 19 curfew limitations, which restricted our ability to adequately investigate frog assemblages during night-time hours. Although we recorded several specimens and calling individuals of the genus *Phrynobatrachus*, our dataset is inconclusive as to how many species were observed. We tentatively assume all of our records to be *Phrynobatrachus keniensis*, but more species could be involved.

Xenopus borealis* vs *Xenopus victorianus: Two species of *Xenopus* may potentially occur in the study area, but these are difficult to distinguish on morphological characters. We tentatively identified all of our field survey records as *X. borealis*, the more likely species to occur here.

Ptychadena mascareniensis: The name *Ptychadena nilotica* is used here over the conventional *Ptychadena mascareniensis*, based on Zimkus et al. (2016).

Amietia nutti* vs *Ametia wittii: Two species of *Amietia* occur in the study area (Channing et al. 2016, Spawls et al. 2019). It can be difficult to distinguish between these two species when dealing with non-adult specimens. We were able to allocate some of the 2021 field survey observations to specific species, but some cases we logged juvenile and tadpole specimens as *Amietia* sp. (*nutti*/*wittei*).

Cacosternum plimptoni* vs *Cacosternum kinangopensis: The two species of dainty frogs that are known to occur in Kenya are classical cases of cryptic species. Species identifications is very difficult and not readily possible when trying to tell them apart based on morphological characters. This is because 1) the two species are morphologically similar and 2) each species display a substantial variety of colour morphs (e.g. Figure 28a) that may be shared between the two taxa. The best ways of separate the two species are by means of molecular and/or call analyses. We did the latter (Figure 28b) and concluded that the populations along the Nairobi-Nakuru-Mau Summit road are *Cacosternum plimptoni*. It is possible that *Cacosternum kinangopensis* also occurs in the general region, but it is more likely that this species will be associated with higher altitude localities towards the Kinangop Plateau.



a) b)

Figure 28: A series of three *Cacosternum* voucher specimens (a) sampled from flooded terrain next to the A104 Rironi to Mau Summit road. These would be difficult to identify based purely on morphology and colouration, because there is much similarity between *Cacosternum plimptoni* and *C. kinangopensis* and much variation within each of these species. We analysed digital recordings of male advertising calls (b) to identify *Cacosternum* choruses within the study area as *C. plimptoni*.

***Tomopterna* spp**: The genus *Tomopterna* is another group of frogs with lots of cryptic species that are extremely difficult to identify based on morphological characters. This is best done by means of molecular and/or call analyses. We observed a number of non-calling specimens during the 2021 field surveys, and have opted to refer to it as *Tomopterna cryptotis* until such time as the tissue samples have been sequenced.

11. APPENDIX III: Photos of herpetology trap arrays 1 to 12


a)


b)


c)


d)


e)


f)

Figure 29: Habitat photos of the first batch of six trap arrays (a–f) that were deployed in the the northern half of the study area during the April field season.

Figure 30: Habitat photos of the second batch of six trap arrays (a–f) that were deployed in the the southern half of the study area during the April field season.

12. APPENDIX IV: All herpetofaunal records of the 2021 field surveys

Table 12: A log of all reptile and amphibian observations of the February and April field surveys.

Scientific name	Latitude	Longitude	Date	Trip	Record_1	Record_2	Abundance	Cell_ID_2km	Cell_ID_1km	Closest_SampID
Trachylepis striata	-0.693333009	36.41956399	2021/02/16	Feb-21	photo	incidental	1	BT53	BT53D	237
Agama caudospinosa	-0.61055	36.38028	2021/02/16	Feb-21	sight	incidental	2	BR48	BR48D	338
Acanthocercus gregorii	-0.54153	36.33799	2021/02/16	Feb-21	sight	incidental	1	BP45	BP45A	432
Trachylepis striata	-0.29952798	35.89990402	2021/02/16	Feb-21	photo	incidental	1	AN31	AN31D	109
Trioceros hoehnelii	-0.300083	35.90025	2021/02/16	Feb-21	photo	incidental	1	AN31	AN31D	109
Trioceros hoehnelii	-0.299713	35.899826	2021/02/16	Feb-21	photo	incidental	1	AN31	AN31D	109
Hemidactylus mabouia	-0.299593	35.89971	2021/02/16	Feb-21	photo	incidental	1	AN31	AN31D	109
Hemidactylus mabouia	-0.30053	35.9007	2021/02/16	Feb-21	sight	incidental	3	AN31	AN31D	109
Boaedon fuliginosus	-0.291512031	35.829491	2021/02/17	Feb-21	tissue/photo	incidental	1	AJ31	AJ31B	243
Phrynobatrachus keniensis	-0.137373023	35.675842	2021/02/17	Feb-21	voucher/tissue/photo	search	1	AA22	AA22C	141
Trachylepis striata	-0.137186022	35.67571199	2021/02/17	Feb-21	sight	search	2	AA22	AA22C	141
Trachylepis striata	-0.137806032	35.67519399	2021/02/17	Feb-21	sight	search	1	AA22	AA22C	141
Amietia wittei	-0.13725	35.6764	2021/02/17	Feb-21	sight	search	10	AA22	AA22C	141
Amietia wittei	-0.13725	35.6764	2021/02/17	Feb-21	voucher/tissue/photo	search	1	AA22	AA22C	141
Amietia wittei	-0.13725	35.6764	2021/02/17	Feb-21	photo	search	1	AA22	AA22C	141
Amietia wittei	-0.13725	35.6764	2021/02/17	Feb-21	photo	search	1	AA22	AA22C	141
Amietia wittei	-0.13725	35.6764	2021/02/17	Feb-21	photo	search	1	AA22	AA22C	141
Amietia wittei	-0.153353037	35.700175	2021/02/17	Feb-21	photo	search	20	AB23	AB23D	81
Amietia wittei	-0.177447991	35.71095899	2021/02/17	Feb-21	photo	search	1	AC25	AC25A	55
Trachylepis striata	-0.177554023	35.71102898	2021/02/17	Feb-21	photo	search	1	AC25	AC25A	55
Trioceros hoehnelii	-0.151389	35.690159	2021/02/17	Feb-21	photo	incidental	2	AB23	AB23C	75
Ptychadena nilotica	-0.29761	35.902161	2021/02/17	Feb-21	tissue/photo	incidental	1	AP31	AP31C	109
Ptychadena nilotica	-0.29761	35.902161	2021/02/17	Feb-21	voucher/tissue/photo	incidental	1	AP31	AP31C	109
Xenopus borealis	-0.29761	35.902161	2021/02/17	Feb-21	voucher/tissue/photo	incidental	1	AP31	AP31C	109
Xenopus borealis	-0.29761	35.902161	2021/02/17	Feb-21	voucher/tissue/photo	incidental	1	AP31	AP31C	109
Trachylepis striata	-0.226664012	35.73318897	2021/02/18	Feb-21	sight	search	1	AD27	AD27D	145
Trachylepis striata	-0.229376983	35.73524304	2021/02/18	Feb-21	photo	search	1	AD27	AD27D	145

Xenopus borealis	-0.229216972	35.735495	2021/02/18	Feb-21	photo	search	3	AD27	AD27D	145
Trachylepis striata	-0.229475973	35.73543004	2021/02/18	Feb-21	photo	search	1	AD27	AD27D	145
Trachylepis striata	-0.229416965	35.73538997	2021/02/18	Feb-21	photo	search	1	AD27	AD27D	145
Adolfus jacksoni	-0.229285033	35.735121	2021/02/18	Feb-21	voucher/tissue/photo	search	1	AD27	AD27D	145
Trachylepis striata	-0.22673903	35.73335401	2021/02/18	Feb-21	photo	search	1	AD27	AD27D	145
Trachylepis striata	-0.175848976	35.72711896	2021/02/18	Feb-21	photo	search	3	AD24	AD24C	144
Amietia wittei	-0.175815029	35.72718602	2021/02/18	Feb-21	photo	search	20	AD24	AD24C	144
Amietia wittei	-0.175815029	35.72718602	2021/02/18	Feb-21	photo	search	10	AD24	AD24C	144
Amietia wittei	-0.175815029	35.72718602	2021/02/18	Feb-21	photo	search	1	AD24	AD24C	144
Amietia wittei	-0.175815029	35.72718602	2021/02/18	Feb-21	photo	search	20	AD24	AD24C	144
Amietia wittei	-0.176168997	35.72716196	2021/02/18	Feb-21	sight	search	20	AD24	AD24C	144
Trachylepis striata	-0.214968994	35.750595	2021/02/18	Feb-21	photo	search	1	AE27	AE27B	116
Trachylepis striata	-0.214856006	35.75058402	2021/02/18	Feb-21	photo	search	1	AE27	AE27B	116
Amietia wittei	-0.208045039	35.75224397	2021/02/18	Feb-21	photo	search	10	AE26	AE26D	174
Ptychadena nilotica	-0.5964	36.38187	2021/02/18	Feb-21	photo	incidental	1	BR48	BR48B	390
Ptychadena nilotica	-0.5832	36.36325	2021/02/18	Feb-21	photo	incidental	1	BQ47	BQ47B	362
Xenopus borealis	-0.22542	35.77015	2021/02/18	Feb-21	voucher/tissue/photo	incidental	10	AF27	AF27D	138
Amietia sp. (nutti/*wittei*)	-0.22387	35.73386	2021/02/18	Feb-21	voucher/tissue/photo	incidental	4	AD27	AD27D	145
Xenopus borealis	-0.22387	35.73386	2021/02/18	Feb-21	voucher/tissue/photo	incidental	10	AD27	AD27D	145
Trioceros hoehnelii	-0.299868	35.900022	2021/02/18	Feb-21	photo	incidental	1	AN31	AN31D	109
Trioceros hoehnelii	-0.299869	35.900006	2021/02/18	Feb-21	photo	incidental	1	AN31	AN31D	109
Trachylepis striata	-0.27731996	36.02276897	2021/02/19	Feb-21	photo	search	1	AV30	AV30D	167
Trachylepis striata	-0.276810005	36.02235097	2021/02/19	Feb-21	photo	search	1	AV30	AV30D	167
Amietia sp. (nutti/*wittei*)	-0.21342203	35.863244	2021/02/19	Feb-21	photo	search	1	AL27	AL27B	290
Lygodactylus keniensis	-0.206401013	35.82243604	2021/02/19	Feb-21	photo	search	1	AJ26	AJ26D	409
Adolfus jacksoni	-0.20754003	35.82134899	2021/02/19	Feb-21	sight	search	1	AJ26	AJ26D	409
Adolfus jacksoni	-0.20743601	35.82151998	2021/02/19	Feb-21	photo	search	1	AJ26	AJ26D	409
Adolfus jacksoni	-0.20743601	35.82151998	2021/02/19	Feb-21	photo	search	1	AJ26	AJ26D	409
Amietia nutti	-0.205842024	35.78534201	2021/02/19	Feb-21	photo	search	5	AG26	AG26D	110
Amietia nutti	-0.206180988	35.78533497	2021/02/19	Feb-21	photo	search	1	AG26	AG26D	110
Amietia nutti	-0.206180988	35.78533497	2021/02/19	Feb-21	photo	search	1	AG26	AG26D	110

Trioceros hoehnelii	-0.229222002	35.73607	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Trioceros hoehnelii	-0.229175985	35.736113	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Trioceros hoehnelii	-0.22862	35.73544	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Amietia nutti	-0.22861	35.73563	2021/02/19	Feb-21	photo	search	10	AD27	AD27D	145
Amietia nutti	-0.22852	35.73555	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Amietia nutti	-0.22846	35.73562	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Amietia nutti	-0.22846	35.73562	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Amietia nutti	-0.22862	35.73566	2021/02/19	Feb-21	voucher/photo	search	1	AD27	AD27D	145
Amietia nutti	-0.22862	35.73566	2021/02/19	Feb-21	voucher/tissue/photo	search	1	AD27	AD27D	145
Amietia nutti	-0.22862	35.73566	2021/02/19	Feb-21	voucher/tissue/photo	search	1	AD27	AD27D	145
Trioceros hoehnelii	-0.228151968	35.73493701	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Trioceros hoehnelii	-0.22638699	35.73331696	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Trioceros hoehnelii	-0.226117009	35.73324102	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Trioceros hoehnelii	-0.22502	35.73354	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Sclerophrys kerinyagae	-0.22856201	35.73502896	2021/02/19	Feb-21	voucher/photo	search	1	AD27	AD27D	145
Sclerophrys kerinyagae	-0.229027038	35.73537304	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Sclerophrys kerinyagae	-0.22875	35.73519	2021/02/19	Feb-21	photo	search	1	AD27	AD27D	145
Hyperolius viridiflavus subsp.	-0.22257	35.73597	2021/02/19	Feb-21	aural	search	10	AD27	AD27D	145
Xenopus borealis	-0.22968	35.73556	2021/02/19	Feb-21	sight	search	2	AD27	AD27D	145
Xenopus borealis	-0.19761	35.83253	2021/02/19	Feb-21	voucher/tissue/photo	incidental	1	AK26	AK26A	244
Xenopus borealis	-0.19761	35.83253	2021/02/19	Feb-21	voucher/tissue/photo	incidental	1	AK26	AK26A	244
Trachylepis striata	-0.287444964	36.02795703	2021/02/20	Feb-21	photo	search	1	AW31	AW31A	105
Trachylepis striata	-0.301177036	36.14960502	2021/02/20	Feb-21	photo	search	1	BC31	BC31D	310
Trachylepis striata	-0.323525034	36.17215401	2021/02/20	Feb-21	photo	search	1	BE33	BE33A	311
Colubridae	-0.324087963	36.17207799	2021/02/20	Feb-21	photo	search	1	BE33	BE33A	311
Afrotyphlops lineolatus	-0.32431704	36.17243598	2021/02/20	Feb-21	photo	search	1	BE33	BE33A	311
Trachylepis striata	-0.324749965	36.15899602	2021/02/20	Feb-21	photo	incidental	1	BD33	BD33A	406
Acanthocercus gregorii	-0.358363995	36.20188898	2021/02/20	Feb-21	photo	search	1	BF35	BF35B	417
Acanthocercus gregorii	-0.372287007	36.22566601	2021/02/20	Feb-21	sight	search	1	BH35	BH35C	404
Amietia sp. (*nutti*/*wittei*)	-0.2138	35.86384	2021/02/20	Feb-21	tissue/photo	incidental	2	AL27	AL27B	290
Xenopus borealis	-0.2138	35.86384	2021/02/20	Feb-21	sight	incidental	3	AL27	AL27B	290

Sclerophrys kerinyagae	-0.29978	35.8996	2021/02/20	Feb-21	tissue/photo	incidental	1	AN31	AN31D	109
Hemidactylus mabouia	-0.299924	35.900045	2021/02/20	Feb-21	photo	incidental	1	AN31	AN31D	109
Trioceros bitaeniatus	-0.514237	36.322142	2021/02/20	Feb-21	photo	incidental	1	BN43	BN43C	429
Trioceros bitaeniatus	-0.514406	36.322093	2021/02/20	Feb-21	photo	incidental	1	BN43	BN43C	429
Agama caudospinosa	-0.410227021	36.260927	2021/02/21	Feb-21	photo	search	1	BK37	BK37C	164
Acanthocercus gregorii	-0.411151964	36.26113202	2021/02/21	Feb-21	photo	search	1	BK37	BK37C	164
Agama caudospinosa	-0.411590002	36.26123403	2021/02/21	Feb-21	photo	search	4	BK37	BK37C	164
Agama caudospinosa	-0.411590002	36.26123403	2021/02/21	Feb-21	photo	search	1	BK37	BK37C	164
Acanthocercus gregorii	-0.411590002	36.26123403	2021/02/21	Feb-21	photo	search	1	BK37	BK37C	164
Agama caudospinosa	-0.414622994	36.26233198	2021/02/21	Feb-21	photo	search	1	BK38	BK38A	164
Acanthocercus gregorii	-0.406652978	36.23397198	2021/02/21	Feb-21	photo	search	1	BH37	BH37D	201
Acanthocercus gregorii	-0.407886961	36.23318299	2021/02/21	Feb-21	photo	search	1	BH37	BH37C	202
Trachylepis striata	-0.40804496	36.23312297	2021/02/21	Feb-21	sight	search	1	BH37	BH37C	202
Acanthocercus gregorii	-0.395890027	36.22325898	2021/02/21	Feb-21	photo	search	1	BG37	BG37B	209
Boaedon fuliginosus	-0.373095023	36.21753397	2021/02/21	Feb-21	photo	search	1	BG35	BG35D	315
Hyperolius viridiflavus subsp.	-0.773255965	36.419234	2021/02/22	Feb-21	aural	incidental	20	BT57	BT57D	944
Hemidactylus mabouia	-0.772378966	36.42072304	2021/02/22	Feb-21	sight	incidental	1	BT57	BT57D	944
Hemidactylus mabouia	-0.772436969	36.42062204	2021/02/22	Feb-21	sight	incidental	1	BT57	BT57D	944
Hemidactylus mabouia	-0.77272	36.42056	2021/02/22	Feb-21	photo	incidental	5	BT57	BT57D	944
Sclerophrys garmani	-0.77259	36.42108	2021/02/22	Feb-21	photo	incidental	1	BT57	BT57D	944
Trachylepis striata	-0.458152983	36.26098601	2021/02/22	Feb-21	sight	search	1	BK40	BK40C	193
Acanthocercus gregorii	-0.456661005	36.262292	2021/02/22	Feb-21	photo	search	1	BK40	BK40A	195
Acanthocercus gregorii	-0.455407994	36.26054001	2021/02/22	Feb-21	photo	search	1	BK40	BK40A	195
Acanthocercus gregorii	-0.451015038	36.26378104	2021/02/22	Feb-21	photo	incidental	1	BK40	BK40A	188
Boaedon fuliginosus	-0.456593027	36.27827201	2021/02/22	Feb-21	photo	search	1	BK40	BK40B	323
Acanthocercus gregorii	-0.457671024	36.27836396	2021/02/22	Feb-21	photo	search	1	BL40	BL40C	323
Acanthocercus gregorii	-0.538362013	36.33616699	2021/02/22	Feb-21	photo	search	1	BP44	BP44C	327
Ptychadena nilotica	-0.39584904	36.21938897	2021/02/23	Feb-21	voucher	search	1	BG37	BG37B	212
Agama caudospinosa	-0.422568033	36.21396999	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Trachylepis varia	-0.42248698	36.21403	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Trachylepis varia	-0.422040978	36.21426101	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192

Leptotyphlops merkeri	-0.422090013	36.21402598	2021/02/23	Feb-21	sight	search	1	BG38	BG38C	192
Trachylepis varia	-0.422109962	36.21405196	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Agama caudospinosa	-0.423566988	36.21518201	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Agama caudospinosa	-0.42387804	36.21532501	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Agama caudospinosa	-0.423332965	36.21524102	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Agama caudospinosa	-0.423332965	36.21524102	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Agama caudospinosa	-0.423332965	36.21524102	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Agama caudospinosa	-0.423332965	36.21524102	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Trachylepis striata	-0.426075021	36.214345	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Trachylepis varia	-0.426221034	36.21449604	2021/02/23	Feb-21	photo	search	1	BG38	BG38C	192
Trachylepis striata	-0.665932987	36.39393398	2021/02/23	Feb-21	photo	search	1	BS52	BS52A	386
Trachylepis varia	-0.614194013	36.39164697	2021/02/23	Feb-21	sight	search	1	BS49	BS49A	338
Trachylepis striata	-0.69325	36.41924	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69325	36.41924	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69325	36.41924	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.6933	36.41937	2021/02/23	Feb-21	photo	incidental	2	BT53	BT53D	237
Trachylepis striata	-0.6933	36.41937	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69338	36.41944	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69338	36.41944	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69338	36.41944	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69338	36.41944	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69338	36.41944	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69338	36.41944	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69338	36.41944	2021/02/23	Feb-21	photo	incidental	2	BT53	BT53D	237
Trachylepis striata	-0.69343	36.41956	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69343	36.41956	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69343	36.41956	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.69343	36.41956	2021/02/23	Feb-21	photo	incidental	1	BT53	BT53D	237
Acanthocercus gregorii	-0.646356968	36.34343502	2021/02/24	Feb-21	photo	search	1	BP50	BP50D	229
Acanthocercus gregorii	-0.646356968	36.34343502	2021/02/24	Feb-21	photo	search	1	BP50	BP50D	229
Acanthocercus gregorii	-0.646344982	36.34438402	2021/02/24	Feb-21	photo	search	1	BP50	BP50D	229

Acanthocercus gregorii	-0.64586604	36.34273496	2021/02/24	Feb-21	photo	search	1	BP50	BP50D	229
Acanthocercus gregorii	-0.64586604	36.34273496	2021/02/24	Feb-21	photo	search	1	BP50	BP50D	229
Agama caudospinosa	-0.72920504	36.45500201	2021/02/24	Feb-21	photo	search	1	BV55	BV55D	379
Acanthocercus gregorii	-0.768638039	36.50573499	2021/02/24	Feb-21	photo	search	1	BY57	BY57D	130
Trachylepis striata	-0.768624041	36.505565	2021/02/24	Feb-21	photo	search	1	BY57	BY57D	130
Trioceros hoehnelii	-0.822584	36.54378	2021/02/24	Feb-21	photo	search	1	CA60	CA60D	123
Trioceros hoehnelii	-0.827372968	36.54976504	2021/02/24	Feb-21	photo	search	1	CB60	CB60C	128
Trioceros hoehnelii	-0.827372968	36.54976504	2021/02/24	Feb-21	photo	search	1	CB60	CB60C	128
Trioceros hoehnelii	-0.827395013	36.54878	2021/02/24	Feb-21	photo	search	1	CB60	CB60C	128
Trioceros hoehnelii	-0.827991972	36.549054	2021/02/24	Feb-21	photo	search	1	CB60	CB60C	128
Cacosternum plimptoni	-0.878810026	36.57135598	2021/02/24	Feb-21	aural	incidental	3	CC63	CC63C	86
Cacosternum plimptoni	-0.8789	36.57111	2021/02/24	Feb-21	sound-clip	incidental	3	CC63	CC63C	86
Cacosternum plimptoni	-0.877864966	36.56933502	2021/02/24	Feb-21	sound-clip	search	10	CC63	CC63C	86
Cacosternum plimptoni	-0.877624992	36.568584	2021/02/24	Feb-21	aural	search	10	CC63	CC63C	86
Cacosternum plimptoni	-0.88484	36.57841	2021/02/24	Feb-21	aural	incidental	10	CC64	CC64B	84
Cacosternum plimptoni	-0.88503	36.57832	2021/02/24	Feb-21	aural	incidental	10	CC64	CC64B	84
Cacosternum plimptoni	-0.895526977	36.59841	2021/02/24	Feb-21	aural	search	5	CD64	CD64D	17
Cacosternum plimptoni	-0.895819003	36.59847898	2021/02/24	Feb-21	aural	search	10	CD64	CD64D	17
Cacosternum plimptoni	-0.896171965	36.59887897	2021/02/24	Feb-21	sound-clip	search	2	CD64	CD64D	17
Kassina senegalensis	-0.896170959	36.59904904	2021/02/24	Feb-21	sound-clip	search	10	CD64	CD64D	17
Phrynobatrachus keniensis	-0.896170959	36.59904904	2021/02/24	Feb-21	aural	search	5	CD64	CD64D	17
Anura (unidentified call #1)	-0.896170959	36.59904904	2021/02/24	Feb-21	aural	search	5	CD64	CD64D	17
Hyperolius viridiflavus subsp.	-0.65388	36.35167	2021/02/24	Feb-21	sound-clip	search	20	BQ51	BQ51A	229
Hyperolius viridiflavus subsp.	-0.65388	36.35167	2021/02/24	Feb-21	aural	search	20	BQ51	BQ51A	229
Hyperolius viridiflavus subsp.	-0.65359	36.35148	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Hyperolius viridiflavus subsp.	-0.65359	36.35148	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Hyperolius viridiflavus subsp.	-0.65335	36.35118	2021/02/24	Feb-21	sound-clip	search	1	BQ51	BQ51A	229
Ptychadena nilotica	-0.65388	36.35167	2021/02/24	Feb-21	voucher/tissue/photo	search	1	BQ51	BQ51A	229
Ptychadena nilotica	-0.65388	36.35167	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Ptychadena nilotica	-0.65388	36.35167	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Ptychadena nilotica	-0.65388	36.35167	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229

Ptychadena nilotica	-0.65398	36.35142	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Ptychadena nilotica	-0.65398	36.35142	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Ptychadena nilotica	-0.65398	36.35142	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Ptychadena nilotica	-0.65398	36.35142	2021/02/24	Feb-21	photo	search	1	BQ51	BQ51A	229
Xenopus borealis	-0.99946	36.63673	2021/02/24	Feb-21	photo	incidental	1	CF70	CF70B	97
Amietia sp. (nutti/*wittei*)	-0.99946	36.63673	2021/02/24	Feb-21	voucher/tissue/photo	incidental	2	CF70	CF70B	97
Amietia sp. (nutti/*wittei*)	-0.99946	36.63673	2021/02/24	Feb-21	voucher	incidental	1	CF70	CF70B	97
Phrynobatrachus keniensis	-0.99946	36.63673	2021/02/24	Feb-21	voucher/tissue/photo	incidental	1	CF70	CF70B	97
Agama caudospinosa	-0.511751985	36.31470404	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Acanthocercus gregorii	-0.51171896	36.31445903	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Acanthocercus gregorii	-0.511789033	36.31424697	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Acanthocercus gregorii	-0.511765983	36.314165	2021/02/25	Feb-21	photo	search	1	BM43	BM43D	429
Agama caudospinosa	-0.511794984	36.31465601	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Trachylepis striata	-0.511810994	36.31497201	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Trachylepis striata	-0.511834966	36.315532	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Trachylepis striata	-0.511834966	36.315532	2021/02/25	Feb-21	sight	search	1	BN43	BN43C	429
Trachylepis striata	-0.511843013	36.31608504	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Acanthocercus gregorii	-0.512067983	36.31779402	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Acanthocercus gregorii	-0.511871008	36.31848796	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Acanthocercus gregorii	-0.511876037	36.31884201	2021/02/25	Feb-21	photo	search	2	BN43	BN43C	429
Acanthocercus gregorii	-0.511878971	36.31934401	2021/02/25	Feb-21	photo	search	1	BN43	BN43C	429
Acanthocercus gregorii	-0.509608984	36.31897403	2021/02/25	Feb-21	photo	incidental	1	BN43	BN43A	429
Agama caudospinosa	-0.482952017	36.30082604	2021/02/25	Feb-21	photo	search	1	BM41	BM41C	427
Agama caudospinosa	-0.483570015	36.30093399	2021/02/25	Feb-21	photo	search	1	BM41	BM41C	427
Acanthocercus gregorii	-0.48364101	36.30098504	2021/02/25	Feb-21	photo	search	1	BM41	BM41C	427
Acanthocercus gregorii	-0.484519014	36.30151796	2021/02/25	Feb-21	sight	search	1	BM41	BM41C	427
Agama caudospinosa	-0.485969	36.30234299	2021/02/25	Feb-21	sight	search	1	BM42	BM42A	427
Acanthocercus gregorii	-0.485215969	36.30205197	2021/02/25	Feb-21	sight	search	1	BM42	BM42A	427
Agama caudospinosa	-0.48328897	36.30096501	2021/02/25	Feb-21	photo	search	1	BM41	BM41C	427
Agama caudospinosa	-0.483154021	36.30089996	2021/02/25	Feb-21	photo	search	2	BM41	BM41C	427
Acanthocercus gregorii	-0.482755965	36.30070902	2021/02/25	Feb-21	photo	search	1	BM41	BM41C	427

Agama caudospinosa	-0.536784036	36.33456504	2021/02/25	Feb-21	photo	search	1	BP44	BP44C	327
Acanthocercus gregorii	-0.540361013	36.336931	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.540306028	36.33704399	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.540614985	36.33722001	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.541089987	36.33761303	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.541380001	36.33790196	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.541784009	36.33832198	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.542059019	36.33864803	2021/02/25	Feb-21	sight	search	1	BP45	BP45A	432
Agama caudospinosa	-0.542432014	36.33899203	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.544033041	36.340225	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	432
Agama caudospinosa	-0.543970009	36.34054301	2021/02/25	Feb-21	photo	search	2	BP45	BP45A	432
Agama caudospinosa	-0.542770978	36.34040404	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	328
Agama caudospinosa	-0.542698978	36.33971396	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	328
Acanthocercus gregorii	-0.542177036	36.33911801	2021/02/25	Feb-21	photo	search	1	BP45	BP45A	328
Acanthocercus gregorii	-0.538240978	36.33612902	2021/02/25	Feb-21	photo	search	1	BP44	BP44C	327
Leptotyphlops merkeri	-0.536540961	36.33502797	2021/02/25	Feb-21	photo	search	1	BP44	BP44C	327
Acanthocercus gregorii	-0.759834023	36.48095003	2021/02/25	Feb-21	photo	search	2	BX57	BX57A	350
Cacosternum plimptoni	-0.897778021	36.598022	2021/02/25	Feb-21	aural	search	10	CD64	CD64D	17
Phrynobatrachus keniensis	-0.896170959	36.59904904	2021/02/25	Feb-21	sound-clip	search	5	CD64	CD64D	17
Anura (unidentified call #1)	-0.896170959	36.59904904	2021/02/25	Feb-21	aural	search	5	CD64	CD64D	17
Kassina senegalensis	-0.896170959	36.59904904	2021/02/25	Feb-21	aural	search	5	CD64	CD64D	17
Cacosternum plimptoni	-0.896171965	36.59887897	2021/02/25	Feb-21	sound-clip	search	5	CD64	CD64D	17
Phrynobatrachus keniensis	-0.915480014	36.60283799	2021/02/26	Feb-21	aural	search	5	CE65	CE65C	28
Anura (unidentified call #1)	-0.915480014	36.60283799	2021/02/26	Feb-21	aural	search	5	CE65	CE65C	28
Phrynobatrachus keniensis	-0.915710013	36.60283699	2021/02/26	Feb-21	sound-clip	search	5	CE65	CE65C	46
Anura (unidentified call #1)	-0.915710013	36.60283699	2021/02/26	Feb-21	sound-clip	search	5	CE65	CE65C	46
Cacosternum plimptoni	-0.915710013	36.60283699	2021/02/26	Feb-21	aural	search	5	CE65	CE65C	46
Kassina senegalensis	-0.915932972	36.602653	2021/02/26	Feb-21	aural	search	2	CE65	CE65C	46
Phrynobatrachus keniensis	-0.916407974	36.60307604	2021/02/26	Feb-21	voucher/photo	search	1	CE65	CE65C	46
Phrynobatrachus keniensis	-0.916407974	36.60307604	2021/02/26	Feb-21	tissue/photo	search	1	CE65	CE65C	46
Phrynobatrachus keniensis	-0.916407974	36.60307604	2021/02/26	Feb-21	photo	search	1	CE65	CE65C	46

Xenopus borealis	-0.941391997	36.623275	2021/02/26	Feb-21	photo	search	10	CF67	CF67A	25
Amietia sp. (nutti/*wittei*)	-0.941391997	36.623275	2021/02/26	Feb-21	sight	search	10	CF67	CF67A	25
Amietia sp. (nutti/*wittei*)	-0.941391997	36.623275	2021/02/26	Feb-21	sight	search	1	CF67	CF67A	25
Amietia wittei	-0.961332042	36.630249	2021/02/26	Feb-21	photo	search	1	CF68	CF68B	99
Amietia sp. (nutti/*wittei*)	-0.960968016	36.63028998	2021/02/26	Feb-21	aural	search	2	CF68	CF68B	99
Xenopus borealis	-1.10488303	36.634305	2021/02/26	Feb-21	photo	search	10	CF76	CF76B	89
Hyperolius viridiflavus ferniquei	-1.104257992	36.63414901	2021/02/26	Feb-21	photo	search	1	CF76	CF76B	89
Hyperolius viridiflavus ferniquei	-1.103316033	36.633932	2021/02/26	Feb-21	photo	search	1	CF76	CF76B	89
Hyperolius viridiflavus ferniquei	-1.103316033	36.633932	2021/02/26	Feb-21	photo	search	1	CF76	CF76B	89
Trachylepis striata	-0.693238964	36.41952996	2021/04/13	Apr-21	photo	incidental	1	BT53	BT53D	237
Trachylepis striata	-0.693365028	36.41949501	2021/04/13	Apr-21	photo	incidental	1	BT53	BT53D	237
Trioceros hoehnelii	-0.300557027	35.90031004	2021/04/13	Apr-21	photo	search	1	AN31	AN31D	109
Trioceros hoehnelii	-0.300591979	35.90030098	2021/04/13	Apr-21	photo	search	1	AN31	AN31D	109
Trioceros hoehnelii	-0.300458036	35.89988801	2021/04/13	Apr-21	photo	search	1	AN31	AN31D	109
Trioceros hoehnelii	-0.300272964	35.89924897	2021/04/13	Apr-21	photo	search	1	AN31	AN31D	109
Trioceros hoehnelii	-0.299687991	35.89980603	2021/04/13	Apr-21	photo	search	1	AN31	AN31D	109
Trioceros hoehnelii	-0.299791005	35.89972297	2021/04/13	Apr-21	sight	search	1	AN31	AN31D	109
Hemidactylus mabouia	-0.299777007	35.89973001	2021/04/13	Apr-21	photo	incidental	1	AN31	AN31D	109
Trioceros hoehnelii	-0.299777007	35.89973001	2021/04/13	Apr-21	photo	search	1	AN31	AN31D	109
Trachylepis striata	-0.214015972	35.72900598	2021/04/14	Apr-21	sight	incidental	1	AD27	AD27A	173
Amietia wittei	-0.137254	35.67639998	2021/04/14	Apr-21	aural	incidental	5	AA22	AA22C	141
Phrynobatrachus keniensis	-0.137254	35.67639998	2021/04/14	Apr-21	aural	incidental	5	AA22	AA22C	141
Anura tadpoles	-0.175974704	35.69581783	2021/04/14	Apr-21	voucher/tissue/photo	incidental	6	AB24	AB24D	63
Amietia sp. (nutti/*wittei*)	-0.175974704	35.69581783	2021/04/14	Apr-21	voucher/photo	incidental	1	AB24	AB24D	63
Trioceros hoehnelii	-0.21208	35.72497	2021/04/14	Apr-21	photo	incidental	1	AD26	AD26C	172
Acanthocercus gregorii	-0.394127984	36.231344	2021/04/14	Apr-21	sight	incidental	1	BH36	BH36C	204
Acanthocercus gregorii	-0.394186992	36.23136504	2021/04/14	Apr-21	sight	incidental	1	BH36	BH36C	204
Tomopterna cryptotis	-0.397188971	36.22374496	2021/04/14	Apr-21	voucher/tissue/photo	incidental	1	BG37	BG37B	209
Gerrhosaurus flavigularus	-0.373542029	36.21719803	2021/04/14	Apr-21	tissue/photo	incidental	1	BG35	BG35D	315
Acanthocercus gregorii	-0.384973017	36.23670003	2021/04/14	Apr-21	photo	incidental	1	BH36	BH36B	367
Trachylepis striata	-0.384975029	36.23670699	2021/04/14	Apr-21	sight	incidental	1	BH36	BH36B	367

Trachylepis striata	-0.384244965	36.23588196	2021/04/14	Apr-21	sight	incidental	1	BH36	BH36B	317
Amietia sp. (nutti/*wittei*)	-0.137318959	35.67647098	2021/04/15	Apr-21	photo	trap	1	AA22	AA22C	141
Trioceros bitaeniatus	-0.19809396	35.83008704	2021/04/15	Apr-21	photo	search	1	AK26	AK26A	244
Trachylepis striata	-0.209344989	35.85828803	2021/04/15	Apr-21	photo	search	1	AL26	AL26D	241
Trachylepis striata	-0.208881972	35.85858601	2021/04/15	Apr-21	sight	search	1	AL26	AL26D	241
Trachylepis striata	-0.208647028	35.85823799	2021/04/15	Apr-21	photo	search	1	AL26	AL26D	241
Trachylepis striata	-0.209480021	35.85734096	2021/04/15	Apr-21	photo	search	1	AL26	AL26D	241
Trachylepis striata	-0.209526038	35.85731699	2021/04/15	Apr-21	photo	search	1	AL26	AL26D	241
Trachylepis striata	-0.209694011	35.85739704	2021/04/15	Apr-21	photo	search	1	AL26	AL26D	241
Trachylepis striata	-0.271655973	36.01553698	2021/04/15	Apr-21	sight	search	1	AV30	AV30A	106
Trachylepis striata	-0.272143967	36.01521998	2021/04/15	Apr-21	photo	search	1	AV30	AV30A	106
Trachylepis striata	-0.271748006	36.012089	2021/04/15	Apr-21	photo	search	1	AV30	AV30A	106
Trachylepis striata	-0.271710036	36.01206897	2021/04/15	Apr-21	photo	search	1	AV30	AV30A	106
Trachylepis striata	-0.271482971	36.01208196	2021/04/15	Apr-21	photo	search	1	AV30	AV30A	106
Amietia sp. (nutti/*wittei*)	-0.22391676	35.73415456	2021/04/15	Apr-21	tissue/photo	incidental	2	AD27	AD27D	145
Ptychadena anchietae	-0.214593066	35.86480438	2021/04/15	Apr-21	voucher/tissue/photo	incidental	1	AL27	AL27B	290
Ptychadena nilotica	-0.2052	35.7853	2021/04/15	Apr-21	sight	incidental	10	AG26	AG26D	110
Ptychadena nilotica	-0.2052	35.7853	2021/04/15	Apr-21	voucher/photo	incidental	1	AG26	AG26D	110
Amietia sp. (nutti/*wittei*)	-0.2052	35.7853	2021/04/15	Apr-21	sight	incidental	10	AG26	AG26D	110
Amietia sp. (nutti/*wittei*)	-0.2052	35.7853	2021/04/15	Apr-21	voucher/tissue/photo	incidental	1	AG26	AG26D	110
Amietia sp. (nutti/*wittei*)	-0.2052	35.7853	2021/04/15	Apr-21	voucher/tissue/photo	incidental	1	AG26	AG26D	110
Anura tadpoles	-0.2052	35.7853	2021/04/15	Apr-21	voucher/tissue/photo	incidental	1	AG26	AG26D	110
Amietia sp. (nutti/*wittei*)	-0.214593066	35.86480438	2021/04/15	Apr-21	photo	incidental	5	AL27	AL27B	290
Amietia sp. (nutti/*wittei*)	-0.214593066	35.86480438	2021/04/15	Apr-21	voucher/photo	incidental	2	AL27	AL27B	290
Xenopus borealis	-0.214593066	35.86480438	2021/04/15	Apr-21	photo	incidental	15	AL27	AL27B	290
Xenopus borealis	-0.214593066	35.86480438	2021/04/15	Apr-21	voucher/photo	incidental	1	AL27	AL27B	290
Anura tadpoles	-0.22391676	35.73415456	2021/04/15	Apr-21	voucher/tissue/photo	incidental	4	AD27	AD27D	145
Anura tadpoles	-0.22391676	35.73415456	2021/04/15	Apr-21	photo	incidental	1	AD27	AD27D	145
Amietia sp. (nutti/*wittei*)	-0.225470178	35.7703006	2021/04/15	Apr-21	voucher	incidental	1	AF27	AF27D	138
Acanthocercus gregorii	-0.383867025	36.21757798	2021/04/15	Apr-21	sight	incidental	1	BG36	BG36B	316
Leptotyphlops merkeri	-0.397188971	36.22374496	2021/04/15	Apr-21	voucher/photo	trap	1	BG37	BG37B	209

Sclerophrys garmani	-0.397172961	36.22374203	2021/04/15	Apr-21	voucher/tissue/photo	trap	1	BG37	BG37B	209
Sclerophrys garmani	-0.397214033	36.22370599	2021/04/15	Apr-21	photo	trap	1	BG37	BG37B	209
Python natalensis/sebae	-0.399479996	36.23683599	2021/04/15	Apr-21	tissue/photo	search	1	BH37	BH37B	206
Agama caudospinosa	-0.385435028	36.23737603	2021/04/15	Apr-21	photo	search	1	BH36	BH36D	367
Acanthocercus gregorii	-0.385802994	36.237844	2021/04/15	Apr-21	sight	search	1	BH36	BH36D	367
Trachylepis striata	-0.38483304	36.23683498	2021/04/15	Apr-21	sight	search	1	BH36	BH36B	367
Agama caudospinosa	-0.417650035	36.256713	2021/04/15	Apr-21	sight	search	1	BJ38	BJ38B	321
Trachylepis striata	-0.419087028	36.25742597	2021/04/15	Apr-21	photo	search	1	BJ38	BJ38B	321
Agama caudospinosa	-0.422752015	36.25083603	2021/04/15	Apr-21	photo	search	1	BJ38	BJ38C	400
Agama caudospinosa	-0.422248011	36.25177204	2021/04/15	Apr-21	photo	search	1	BJ38	BJ38D	400
Agama caudospinosa	-0.422753021	36.25083896	2021/04/15	Apr-21	photo	search	1	BJ38	BJ38C	400
Agama caudospinosa	-0.42229604	36.25168998	2021/04/15	Apr-21	photo	search	1	BJ38	BJ38D	400
Trioceros bitaeniatus	-0.418423014	36.25562604	2021/04/15	Apr-21	photo	search	1	BJ38	BJ38B	321
Acanthocercus gregorii	-0.470597008	36.28782	2021/04/15	Apr-21	photo	search	1	BL41	BL41B	398
Aparallactus jacksoni	-0.464022998	36.28069597	2021/04/15	Apr-21	voucher/tissue/photo	search	1	BL40	BL40C	424
Xenopus borealis	-0.197264487	35.83459307	2021/04/16	Apr-21	voucher/photo	incidental	1	AK26	AK26A	244
Amietia sp. (nutti/*wittei*)	-0.2056	35.8004	2021/04/16	Apr-21	voucher/tissue/photo	incidental	1	AH26	AH26C	170
Trachylepis striata	-0.226290012	35.73225296	2021/04/16	Apr-21	photo	incidental	2	AD27	AD27D	145
Xenopus borealis	-0.163501007	35.68414402	2021/04/16	Apr-21	photo	search	20	AA24	AA24B	87
Amietia wittei	-0.163501007	35.68414402	2021/04/16	Apr-21	photo	search	10	AA24	AA24B	87
Trioceros hoehnelii	-0.16348	35.68421	2021/04/16	Apr-21	photo	search	1	AA24	AA24B	87
Trioceros hoehnelii	-0.175648984	35.69534501	2021/04/16	Apr-21	photo	search	1	AB24	AB24D	63
Trioceros hoehnelii	-0.175546976	35.69542204	2021/04/16	Apr-21	photo	search	1	AB24	AB24D	63
Amietia sp. (nutti/*wittei*)	-0.175928017	35.695501	2021/04/16	Apr-21	photo	search	1	AB24	AB24D	63
Trioceros hoehnelii	-0.175279006	35.69570099	2021/04/16	Apr-21	photo	search	1	AB24	AB24D	63
Trioceros hoehnelii	-0.174962003	35.69607298	2021/04/16	Apr-21	photo	search	1	AB24	AB24D	63
Trioceros hoehnelii	-0.174913974	35.696034	2021/04/16	Apr-21	photo	search	1	AB24	AB24D	63
Trioceros hoehnelii	-0.198968025	35.72416602	2021/04/16	Apr-21	photo	search	1	AD26	AD26A	143
Trachylepis striata	-0.209812028	35.72549899	2021/04/16	Apr-21	sight	search	1	AD26	AD26C	172
Trachylepis striata	-0.209785961	35.72509599	2021/04/16	Apr-21	sight	search	1	AD26	AD26C	172
Acanthocercus gregorii	-0.379945971	36.21609597	2021/04/16	Apr-21	photo	search	1	BG36	BG36B	315

Acanthocercus gregorii	-0.37994002	36.21609103	2021/04/16	Apr-21	sight	incidental	1	BG36	BG36B	315
Acanthocercus gregorii	-0.374776013	36.21560899	2021/04/16	Apr-21	photo	incidental	1	BG35	BG35D	315
Acanthocercus gregorii	-0.374777019	36.21561301	2021/04/16	Apr-21	photo	incidental	1	BG35	BG35D	315
Gerrhosaurus flavigularus	-0.373582011	36.21722301	2021/04/16	Apr-21	photo	trap	1	BG35	BG35D	315
Agama caudospinosa	-0.387296984	36.21933097	2021/04/16	Apr-21	sight	incidental	1	BG36	BG36D	210
Acanthocercus gregorii	-0.390809001	36.22272396	2021/04/16	Apr-21	photo	incidental	1	BG36	BG36D	210
Trachylepis striata	-0.391967967	36.22375301	2021/04/16	Apr-21	sight	incidental	1	BG36	BG36D	210
Acanthocercus gregorii	-0.391963022	36.22375603	2021/04/16	Apr-21	photo	incidental	1	BG36	BG36D	210
Trachylepis striata	-0.384924989	36.23671998	2021/04/16	Apr-21	photo	search	1	BH36	BH36B	367
Trachylepis striata	-0.448043989	36.26345197	2021/04/16	Apr-21	sight	search	1	BK39	BK39C	197
Trachylepis striata	-0.448426958	36.26221103	2021/04/16	Apr-21	photo	search	1	BK40	BK40A	197
Trachylepis striata	-0.448429976	36.26221103	2021/04/16	Apr-21	sight	search	1	BK40	BK40A	197
Trachylepis striata	-0.44842897	36.26221002	2021/04/16	Apr-21	sight	search	1	BK40	BK40A	197
Agama caudospinosa	-0.448424025	36.262206	2021/04/16	Apr-21	photo	search	1	BK40	BK40A	197
Acanthocercus gregorii	-0.448456965	36.26218001	2021/04/16	Apr-21	photo	incidental	1	BK40	BK40A	197
Acanthocercus gregorii	-0.447207978	36.26561299	2021/04/16	Apr-21	sight	incidental	1	BK39	BK39C	322
Acanthocercus gregorii	-0.447066994	36.26599403	2021/04/16	Apr-21	sight	search	1	BK39	BK39C	322
Acanthocercus gregorii	-0.447060959	36.26556404	2021/04/16	Apr-21	photo	search	1	BK39	BK39C	322
Hemidactylus mabouia	-0.356985005	36.202856	2021/04/16	Apr-21	photo	search	1	BF34	BF34D	417
Trachylepis striata	-0.358116981	36.20258401	2021/04/16	Apr-21	sight	incidental	1	BF35	BF35B	417
Trachylepis striata	-0.358088985	36.20258803	2021/04/16	Apr-21	sight	incidental	1	BF35	BF35B	417
Sclerophrys kerinyagae	-0.229235999	35.735883	2021/04/17	Apr-21	photo	trap	1	AD27	AD27D	145
Sclerophrys kerinyagae	-0.229235999	35.735883	2021/04/17	Apr-21	photo	trap	1	AD27	AD27D	145
Sclerophrys kerinyagae	-0.174787994	35.69597801	2021/04/17	Apr-21	photo	incidental	1	AB24	AB24D	63
Trioceros hoehnelii	-0.196269974	35.71407999	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	62
Trioceros hoehnelii	-0.196306016	35.71409902	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	62
Trioceros hoehnelii	-0.196696026	35.71448299	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	62
Trioceros hoehnelii	-0.196220018	35.71656397	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	57
Trioceros hoehnelii	-0.193879036	35.71601302	2021/04/17	Apr-21	photo	search	1	AC25	AC25D	57
Trioceros hoehnelii	-0.193869984	35.71599601	2021/04/17	Apr-21	photo	search	1	AC25	AC25D	57
Trioceros hoehnelii	-0.19374501	35.71596902	2021/04/17	Apr-21	photo	search	1	AC25	AC25D	57

Trioceros hoehnelii	-0.19374501	35.71596902	2021/04/17	Apr-21	photo	search	1	AC25	AC25D	57
Xenopus borealis	-0.194125967	35.71586299	2021/04/17	Apr-21	photo	search	10	AC25	AC25D	57
Amietia sp. (nutti/*wittei*)	-0.199256027	35.720409	2021/04/17	Apr-21	photo	search	10	AC26	AC26B	112
Amietia sp. (nutti/*wittei*)	-0.199256027	35.720409	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	112
Amietia sp. (nutti/*wittei*)	-0.199284023	35.720438	2021/04/17	Apr-21	photo	search	2	AC26	AC26B	112
Amietia sp. (nutti/*wittei*)	-0.199432969	35.720568	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	112
Amietia sp. (nutti/*wittei*)	-0.199432969	35.720568	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	112
Trioceros hoehnelii	-0.199411009	35.72049198	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	112
Amietia sp. (nutti/*wittei*)	-0.200620014	35.72076296	2021/04/17	Apr-21	photo	search	10	AC26	AC26B	112
Trioceros hoehnelii	-0.197975021	35.72107603	2021/04/17	Apr-21	photo	search	1	AC26	AC26B	112
Lygodactylus keniensis	-0.297709024	36.13774404	2021/04/17	Apr-21	voucher/tissue/photo	search	1	BC31	BC31C	412
Lygodactylus keniensis	-0.297709024	36.13774404	2021/04/17	Apr-21	photo	search	1	BC31	BC31C	412
Lygodactylus keniensis	-0.297709024	36.13774404	2021/04/17	Apr-21	photo	search	1	BC31	BC31C	412
Lygodactylus keniensis	-0.297709024	36.13774404	2021/04/17	Apr-21	photo	search	1	BC31	BC31C	412
Lygodactylus keniensis	-0.297709024	36.13774404	2021/04/17	Apr-21	photo	search	1	BC31	BC31C	412
Trachylepis striata	-0.297718998	36.13775401	2021/04/17	Apr-21	sight	search	1	BC31	BC31C	412
Sclerophrys garmani	-0.39705704	36.22378998	2021/04/17	Apr-21	photo	trap	1	BG37	BG37B	209
Sclerophrys garmani	-0.397062991	36.22379802	2021/04/17	Apr-21	photo	trap	1	BG37	BG37B	209
Tomopterna cryptotis	-0.397067014	36.22379802	2021/04/17	Apr-21	photo	trap	1	BG37	BG37B	209
Psammophis mossambicus	-0.37342703	36.21758804	2021/04/17	Apr-21	photo	search	1	BG35	BG35D	315
Acanthocercus gregorii	-0.370051973	36.22685901	2021/04/17	Apr-21	photo	incidental	1	BH35	BH35C	404
Trachylepis striata	-0.360394008	36.21925897	2021/04/17	Apr-21	sight	search	1	BG35	BG35B	368
Adolfus jacksoni	-0.360442037	36.21945703	2021/04/17	Apr-21	photo	search	1	BG35	BG35B	368
Amietia sp. (nutti/*wittei*)	-0.360437008	36.21928101	2021/04/17	Apr-21	sight	search	3	BG35	BG35B	368
Amietia sp. (nutti/*wittei*)	-0.360488975	36.21920499	2021/04/17	Apr-21	photo	search	2	BG35	BG35B	368
Amietia sp. (nutti/*wittei*)	-0.360652003	36.218832	2021/04/17	Apr-21	sight	search	2	BG35	BG35B	368
Acanthocercus gregorii	-0.380705036	36.241383	2021/04/17	Apr-21	photo	incidental	1	BH36	BH36B	318
Acanthocercus gregorii	-0.381755959	36.23474596	2021/04/17	Apr-21	photo	incidental	1	BH36	BH36B	317
Trioceros bitaeniatus	-0.481144963	36.29553697	2021/04/17	Apr-21	photo	search	1	BL41	BL41D	324
Trachylepis striata	-0.478756959	36.29487396	2021/04/17	Apr-21	sight	search	1	BL41	BL41D	324
Trachylepis striata	-0.478752013	36.29487396	2021/04/17	Apr-21	sight	search	1	BL41	BL41D	324

Trachylepis striata	-0.455167014	36.27665799	2021/04/17	Apr-21	sight	search	1	BK40	BK40B	423
Acanthocercus gregorii	-0.455183024	36.27670904	2021/04/17	Apr-21	photo	search	1	BK40	BK40B	423
Xenopus borealis	-0.2138	35.86384	2021/04/18	Apr-21	sight	incidental	15	AL27	AL27B	290
Xenopus borealis	-0.2138	35.86384	2021/04/18	Apr-21	voucher/photo	incidental	1	AL27	AL27B	290
Xenopus borealis	-0.2138	35.86384	2021/04/18	Apr-21	voucher/photo	incidental	1	AL27	AL27B	290
Adolfus jacksoni	-0.243561007	35.85929596	2021/04/18	Apr-21	photo	search	1	AL28	AL28D	243
Adolfus jacksoni	-0.243853033	35.85941297	2021/04/18	Apr-21	photo	search	1	AL28	AL28D	243
Trioceros hoehnelii	-0.136363003	35.67757999	2021/04/18	Apr-21	photo	incidental	1	AA22	AA22D	141
Varanus niloticus	-0.187373003	35.81705502	2021/04/18	Apr-21	photo	search	1	AJ25	AJ25C	298
Trachylepis striata	-0.234132037	35.90255999	2021/04/18	Apr-21	photo	search	1	AP28	AP28A	266
Kassina senegalensis	-0.18806	35.81686	2021/04/18	Apr-21	sound-clip	search	20	AJ25	AJ25C	298
Ptychadena nilotica	-0.18804	35.81686	2021/04/18	Apr-21	photo	search	10	AJ25	AJ25C	298
Ptychadena nilotica	-0.18804	35.81685	2021/04/18	Apr-21	photo	search	1	AJ25	AJ25C	298
Ptychadena nilotica	-0.18803	35.81687	2021/04/18	Apr-21	photo	search	1	AJ25	AJ25C	298
Ptychadena nilotica	-0.18804	35.81688	2021/04/18	Apr-21	photo	search	1	AJ25	AJ25C	298
Hyperolius viridiflavus viridiflavus	-0.18784	35.81699	2021/04/18	Apr-21	photo	search	10	AJ25	AJ25C	298
Hyperolius viridiflavus viridiflavus	-0.18774	35.81702	2021/04/18	Apr-21	photo	search	1	AJ25	AJ25C	298
Hyperolius viridiflavus viridiflavus	-0.18733	35.81715	2021/04/18	Apr-21	photo	search	1	AJ25	AJ25C	298
Hyperolius viridiflavus viridiflavus	-0.18733	35.81715	2021/04/18	Apr-21	aural	search	20	AJ25	AJ25C	298
Hyperolius viridiflavus viridiflavus	-0.18804	35.81684	2021/04/18	Apr-21	sound-clip	search	10	AJ25	AJ25C	298
Sclerophrys garmani	-0.200696038	35.83824598	2021/04/18	Apr-21	photo/sound-clip	incidental	1	AK26	AK26A	244
Trachylepis striata	-0.331958989	35.94476304	2021/04/18	Apr-21	sight	search	1	AR33	AR33C	132
Trioceros hoehnelii	-0.282478016	36.04761997	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trioceros hoehnelii	-0.282448009	36.04756398	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trioceros hoehnelii	-0.282414984	36.04732401	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trioceros hoehnelii	-0.282440968	36.04731998	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trioceros hoehnelii	-0.282412972	36.04718504	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trioceros hoehnelii	-0.282307025	36.04709996	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trachylepis striata	-0.282353964	36.046101	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trachylepis striata	-0.282357987	36.04610201	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410
Trachylepis striata	-0.282428982	36.04517204	2021/04/18	Apr-21	photo	search	1	AX30	AX30C	410

Trachylepis striata	-0.282556973	36.04359498	2021/04/18	Apr-21	sight	search	1	AW30	AW30D	410
Trachylepis striata	-0.287402971	36.05101104	2021/04/18	Apr-21	photo	search	1	AX31	AX31A	411
Trachylepis striata	-0.287415041	36.051004	2021/04/18	Apr-21	photo	search	1	AX31	AX31A	411
Acanthocercus gregorii	-0.275334036	36.08830397	2021/04/18	Apr-21	photo	search	1	AZ30	AZ30A	309
Trachylepis striata	-0.275354991	36.088367	2021/04/18	Apr-21	sight	search	1	AZ30	AZ30A	309
Trachylepis striata	-0.275334036	36.088323	2021/04/18	Apr-21	sight	search	1	AZ30	AZ30A	309
Trachylepis striata	-0.275537968	36.08788303	2021/04/18	Apr-21	photo	search	1	AZ30	AZ30A	309
Trachylepis striata	-0.275598988	36.08776803	2021/04/18	Apr-21	sight	search	1	AZ30	AZ30A	309
Trachylepis striata	-0.275573004	36.08789904	2021/04/18	Apr-21	photo	search	1	AZ30	AZ30A	309
Trachylepis striata	-0.348992022	36.17988699	2021/04/18	Apr-21	photo	incidental	1	BE34	BE34D	313
Boaedon fuliginosus	-0.346239991	36.17994198	2021/04/18	Apr-21	photo	search	1	BE34	BE34B	313
Philothamnus battersbeyi	-0.346535034	36.180032	2021/04/18	Apr-21	photo	search	1	BE34	BE34B	313
Trachylepis striata	-0.348370001	36.17992303	2021/04/18	Apr-21	photo	search	1	BE34	BE34B	313
Acanthocercus gregorii	-0.385087011	36.23651496	2021/04/18	Apr-21	photo	incidental	1	BH36	BH36B	367
Acanthocercus gregorii	-0.387346018	36.23113001	2021/04/18	Apr-21	photo	incidental	1	BH36	BH36C	403
Sclerophrys garmani	-0.397065002	36.22378604	2021/04/18	Apr-21	photo	trap	1	BG37	BG37B	209
Adolfus jacksoni	-0.397137003	36.22374999	2021/04/18	Apr-21	photo	trap	1	BG37	BG37B	209
Acanthocercus gregorii	-0.384344961	36.23591096	2021/04/18	Apr-21	photo	incidental	1	BH36	BH36B	317
Trachylepis striata	-0.33186201	35.94503503	2021/04/18	Apr-21	sight	search	1	AR33	AR33C	132
Psammophis sudanensis	-0.61099	36.38109	2021/04/19	Apr-21	photo	incidental	1	BR48	BR48D	338
Trioceros bitaeniatus	-0.20495	35.87253	2021/04/19	Apr-21	photo	incidental	1	AM26	AM26C	246
Anura tadpoles	-0.455179503	36.27577663	2021/04/19	Apr-21	photo	incidental	20	BK40	BK40B	423
Trioceros hoehnelii	-0.219929991	35.77257503	2021/04/19	Apr-21	photo	incidental	1	AF27	AF27B	136
Trioceros bitaeniatus	-0.220442964	35.86864103	2021/04/19	Apr-21	photo	search	1	AM27	AM27A	268
Trachylepis striata	-0.220442964	35.86864103	2021/04/19	Apr-21	photo	search	1	AM27	AM27A	268
Trachylepis striata	-0.22035202	35.86848596	2021/04/19	Apr-21	photo	search	1	AM27	AM27A	268
Trachylepis striata	-0.220351014	35.86844497	2021/04/19	Apr-21	sight	search	1	AM27	AM27A	268
Trachylepis striata	-0.22011104	35.86868	2021/04/19	Apr-21	photo	search	1	AM27	AM27A	268
Trioceros bitaeniatus	-0.218448993	35.86960402	2021/04/19	Apr-21	photo	search	1	AM27	AM27A	268
Trioceros bitaeniatus	-0.218086978	35.86993896	2021/04/19	Apr-21	photo	search	1	AM27	AM27A	268
Trachylepis striata	-0.229241028	35.88808201	2021/04/19	Apr-21	photo	search	1	AN27	AN27C	264

Trachylepis striata	-0.229004994	35.88815804	2021/04/19	Apr-21	photo	search	1	AN27	AN27C	264
Trachylepis striata	-0.227291984	35.88904099	2021/04/19	Apr-21	photo	search	1	AN27	AN27C	273
Hemidactylus mabouia	-0.29971	35.89975	2021/04/19	Apr-21	photo	incidental	1	AN31	AN31D	109
Trachylepis varia	-0.446661981	36.26080496	2021/04/19	Apr-21	photo	search	1	BK39	BK39C	197
Agama caudospinosa	-0.447881967	36.27791896	2021/04/19	Apr-21	photo	search	1	BK39	BK39D	399
Agama caudospinosa	-0.447859	36.277867	2021/04/19	Apr-21	photo	search	1	BK39	BK39D	399
Acanthocercus gregorii	-0.447779959	36.27752703	2021/04/19	Apr-21	sight	search	1	BK39	BK39D	399
Acanthocercus gregorii	-0.448040972	36.27805601	2021/04/19	Apr-21	sight	search	1	BK39	BK39D	399
Acanthocercus gregorii	-0.448042983	36.27806196	2021/04/19	Apr-21	photo	search	1	BK39	BK39D	399
Acanthocercus gregorii	-0.448043989	36.27806498	2021/04/19	Apr-21	photo	search	1	BK39	BK39D	399
Acanthocercus gregorii	-0.447985986	36.27803497	2021/04/19	Apr-21	photo	search	1	BK39	BK39D	399
Amietia sp. (nutti/*wittei*)	-0.44484403	36.28097098	2021/04/19	Apr-21	sight	search	1	BL39	BL39C	399
Amietia sp. (nutti/*wittei*)	-0.444872025	36.28097903	2021/04/19	Apr-21	sight	search	1	BL39	BL39C	399
Amietia sp. (nutti/*wittei*)	-0.444887029	36.280989	2021/04/19	Apr-21	sight	search	1	BL39	BL39C	399
Amietia sp. (nutti/*wittei*)	-0.444899015	36.28099303	2021/04/19	Apr-21	sight	search	1	BL39	BL39C	399
Amietia sp. (nutti/*wittei*)	-0.444946038	36.28102303	2021/04/19	Apr-21	sight	search	1	BL39	BL39C	399
Trachylepis striata	-0.410863962	36.25237101	2021/04/19	Apr-21	photo	search	1	BJ37	BJ37D	214
Leptotyphlops merkeri	-0.397731028	36.23571198	2021/04/19	Apr-21	voucher/tissue/photo	trap	1	BH37	BH37B	208
Agama caudospinosa	-0.40768303	36.24836404	2021/04/19	Apr-21	photo	incidental	1	BJ37	BJ37C	213
Agama caudospinosa	-0.407657968	36.248386	2021/04/19	Apr-21	photo	incidental	1	BJ37	BJ37C	213
Agama caudospinosa	-0.407998022	36.24885497	2021/04/19	Apr-21	sight	search	1	BJ37	BJ37C	213
Hemidactylus mabouia	-0.299854958	35.89989999	2021/04/19	Apr-21	photo	incidental	1	AN31	AN31D	109
Hemidactylus mabouia	-0.299641974	35.89987904	2021/04/19	Apr-21	photo	incidental	1	AN31	AN31D	109
Hemidactylus mabouia	-0.299625	35.899721	2021/04/19	Apr-21	sight	incidental	1	AN31	AN31D	109
Trioceros hoehnelii	-0.299702995	35.89970101	2021/04/19	Apr-21	photo	incidental	1	AN31	AN31D	109
Trachylepis striata	-0.276744962	36.02234996	2021/04/20	Apr-21	photo	search	1	AV30	AV30D	167
Trioceros bitaeniatus	-0.204086015	35.83784399	2021/04/20	Apr-21	photo	search	2	AK26	AK26A	244
Trachylepis striata	-0.203268025	35.836351	2021/04/20	Apr-21	photo	search	1	AK26	AK26A	244
Lygodactylus keniensis	-0.20328898	35.83637204	2021/04/20	Apr-21	photo	search	1	AK26	AK26A	244
Trachylepis striata	-0.20333902	35.83646801	2021/04/20	Apr-21	photo	search	1	AK26	AK26A	244
Lygodactylus keniensis	-0.203355029	35.83648201	2021/04/20	Apr-21	photo	search	1	AK26	AK26A	244

Trachylepis striata	-0.203384031	35.83652199	2021/04/20	Apr-21	photo	search	1	AK26	AK26A	244
Trioceros hoehnelii	-0.136437016	35.67750203	2021/04/20	Apr-21	photo	incidental	1	AA22	AA22D	141
Adolfus jacksoni	-0.136437016	35.67750203	2021/04/20	Apr-21	photo	incidental	1	AA22	AA22D	141
Adolfus jacksoni	-0.136437016	35.67750203	2021/04/20	Apr-21	sight	incidental	1	AA22	AA22D	141
Adolfus jacksoni	-0.136542963	35.67759197	2021/04/20	Apr-21	photo	incidental	1	AA22	AA22D	141
Trioceros hoehnelii	-0.137712993	35.67699996	2021/04/20	Apr-21	photo	incidental	1	AA22	AA22C	141
Trioceros hoehnelii	-0.137042021	35.677481	2021/04/20	Apr-21	photo	incidental	1	AA22	AA22D	141
Trioceros bitaeniatus	-0.26050603	35.99456596	2021/04/20	Apr-21	photo	search	1	AU29	AU29C	168
Xenopus borealis	-0.260493038	35.99455297	2021/04/20	Apr-21	photo	search	1	AU29	AU29C	168
Acanthocercus gregorii	-0.353334015	36.19003102	2021/04/20	Apr-21	photo	search	1	BF34	BF34C	415
Psammophis mossambicus	-0.373463994	36.21718001	2021/04/20	Apr-21	photo	trap	1	BG35	BG35D	315
Psammophis mossambicus	-0.375502976	36.21780898	2021/04/20	Apr-21	photo	search	1	BG35	BG35D	315
Hemidactylus mabouia	-0.77259304	36.42080803	2021/04/20	Apr-21	sight	search	1	BT57	BT57D	944
Hemidactylus mabouia	-0.772497989	36.42059597	2021/04/20	Apr-21	sight	search	1	BT57	BT57D	944
Hemidactylus mabouia	-0.772353988	36.42067702	2021/04/20	Apr-21	sight	search	1	BT57	BT57D	944
Hemidactylus mabouia	-0.772280982	36.42093301	2021/04/20	Apr-21	sight	search	1	BT57	BT57D	944
Hemidactylus mabouia	-0.772063974	36.42103502	2021/04/20	Apr-21	photo	search	1	BT57	BT57D	944
Cacosternum plimptoni	-0.894751986	36.62518197	2021/04/21	Apr-21	aural	incidental	1	CF64	CF64C	19
Acanthocercus gregorii	-1.006389968	36.60402202	2021/04/21	Apr-21	sight	incidental	1	CE70	CE70C	906
Anura tadpoles	-0.916134389	36.60789412	2021/04/21	Apr-21	sight	incidental	20	CE65	CE65C	27
Anura tadpoles	-0.916134389	36.60789412	2021/04/21	Apr-21	voucher/photo	incidental	1	CE65	CE65C	27
Anura tadpoles	-0.916134389	36.60789412	2021/04/21	Apr-21	voucher/photo	incidental	1	CE65	CE65C	27
Agama caudospinosa	-0.616476992	36.39151596	2021/04/21	Apr-21	sight	incidental	1	BS49	BS49A	216
Agama caudospinosa	-0.616513034	36.39140298	2021/04/21	Apr-21	sight	incidental	1	BS49	BS49A	216
Agama caudospinosa	-0.616264008	36.39174999	2021/04/21	Apr-21	photo	incidental	1	BS49	BS49A	216
Acanthocercus gregorii	-0.90739198	36.51353301	2021/04/22	Apr-21	photo	search	1	BZ65	BZ65A	960
Acanthocercus gregorii	-0.935383011	36.53966996	2021/04/22	Apr-21	photo	search	2	CA66	CA66D	959
Acanthocercus gregorii	-0.935350992	36.53969804	2021/04/22	Apr-21	photo	search	1	CA66	CA66D	959
Xenopus borealis	-1.041258015	36.62733503	2021/04/22	Apr-21	photo	search	20	CF72	CF72C	94
Xenopus borealis	-1.04057204	36.627647	2021/04/22	Apr-21	photo	search	10	CF72	CF72C	94
Xenopus borealis	-1.040597018	36.62768003	2021/04/22	Apr-21	photo	search	50	CF72	CF72C	94

Xenopus borealis	-1.040597018	36.62768003	2021/04/22	Apr-21	photo	search	10	CF72	CF72C	94
Kassina senegalensis	-1.040419992	36.62758498	2021/04/22	Apr-21	photo	search	1	CF72	CF72C	94
Ptychadena nilotica	-1.040442036	36.62748297	2021/04/22	Apr-21	photo	search	3	CF72	CF72C	94
Ptychadena nilotica	-1.04051	36.62752	2021/04/22	Apr-21	photo	search	1	CF72	CF72C	94
Ptychadena nilotica	-1.04051	36.62752	2021/04/22	Apr-21	photo	search	1	CF72	CF72C	94
Phrynobatrachus keniensis	-1.04051	36.62752	2021/04/22	Apr-21	aural	search	1	CF72	CF72C	94
Phrynobatrachus keniensis	-1.038195016	36.626712	2021/04/22	Apr-21	sound-clip	search	1	CF72	CF72C	94
Xenopus borealis	-1.038013967	36.62683798	2021/04/22	Apr-21	photo	search	20	CF72	CF72C	94
Ptychadena nilotica	-1.037564026	36.62683798	2021/04/22	Apr-21	sight	search	2	CF72	CF72C	94
Xenopus borealis	-1.036564987	36.62649399	2021/04/22	Apr-21	photo	search	10	CF72	CF72C	95
Hyperolius viridiflavus ferniquei	-1.036920967	36.62623004	2021/04/22	Apr-21	photo	search	1	CF72	CF72C	95
Hyperolius viridiflavus ferniquei	-1.036920967	36.62623004	2021/04/22	Apr-21	photo	search	1	CF72	CF72C	95
Hyperolius viridiflavus ferniquei	-1.036920967	36.62623004	2021/04/22	Apr-21	photo	search	1	CF72	CF72C	95
Hyperolius viridiflavus ferniquei	-1.036920967	36.62623004	2021/04/22	Apr-21	photo	search	1	CF72	CF72C	95
Bufonidae	-0.923857978	36.60932299	2021/04/22	Apr-21	photo	search	10	CE66	CE66A	45
Phrynobatrachus keniensis	-0.897508962	36.59774004	2021/04/22	Apr-21	photo	search	5	CD64	CD64D	17
Cacosternum plimptoni	-0.897508962	36.59774004	2021/04/22	Apr-21	aural	search	1	CD64	CD64D	17
Hyperolius viridiflavus ferniquei	-0.837999964	36.55112098	2021/04/22	Apr-21	sight	search	10	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837999964	36.55112098	2021/04/22	Apr-21	aural	search	20	CB61	CB61C	128
Hyperolius glandicolor	-0.837999964	36.55112098	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius glandicolor	-0.837999964	36.55112098	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.838085962	36.55113003	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Trioceros hoehnelii	-0.838170033	36.55113003	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Trioceros hoehnelii	-0.838170033	36.55113003	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Trioceros hoehnelii	-0.838170033	36.55113003	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Trioceros hoehnelii	-0.838170033	36.55113003	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.838317974	36.55090498	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius glandicolor	-0.838317974	36.55090498	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.838317974	36.55090498	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.838317974	36.55090498	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.838366002	36.55095602	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128

Trioceros hoehnelii	-0.838366002	36.55095602	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.838366002	36.55095602	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Amietia nutti	-0.838294001	36.55098301	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Amietia nutti	-0.838294001	36.55098301	2021/04/22	Apr-21	photo	search	2	CB61	CB61C	128
Trioceros hoehnelii	-0.838366002	36.55087899	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius glandicolor	-0.837605009	36.55097103	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837537032	36.55092903	2021/04/22	Apr-21	photo	search	2	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837943973	36.550376	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius glandicolor	-0.837943973	36.550376	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837943973	36.550376	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837943973	36.55020802	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.838198029	36.55020802	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Trioceros hoehnelii	-0.838009017	36.55015497	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Trioceros hoehnelii	-0.838050004	36.55017097	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Trioceros hoehnelii	-0.837988984	36.55020601	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837433012	36.55070398	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837433012	36.55070398	2021/04/22	Apr-21	photo	search	1	CB61	CB61C	128
Hyperolius viridiflavus ferniquei	-0.837433012	36.55070398	2021/04/22	Apr-21	sight	search	10	CB61	CB61C	128
Xenopus borealis	-1.1034	36.633	2021/04/22	Apr-21	voucher/photo	incidental	2	CF76	CF76B	89
Xenopus borealis	-1.1034	36.633	2021/04/22	Apr-21	sight	incidental	50	CF76	CF76B	89
Amietia sp. (nutti/*wittei*)	-0.954207759	36.6312503	2021/04/22	Apr-21	voucher/photo	incidental	1	CF67	CF67D	152
Phrynobatrachus keniensis	-0.642614029	36.39295296	2021/04/22	Apr-21	sound-clip	incidental	10	BS50	BS50C	251
Phrynobatrachus keniensis	-0.632898984	36.39012599	2021/04/22	Apr-21	voucher/tissue/photo	trap	1	BS50	BS50A	219
Agama caudospinosa	-0.616621999	36.391407	2021/04/22	Apr-21	sight	incidental	1	BS49	BS49A	216
Acanthocercus gregorii	-0.482628979	36.30037199	2021/04/22	Apr-21	sight	search	1	BM41	BM41C	427
Acanthocercus gregorii	-0.482698968	36.30070802	2021/04/22	Apr-21	photo	search	1	BM41	BM41C	427
Agama caudospinosa	-0.482830983	36.30072897	2021/04/22	Apr-21	sight	search	1	BM41	BM41C	427
Acanthocercus gregorii	-0.482762	36.30070802	2021/04/22	Apr-21	photo	search	1	BM41	BM41C	427
Agama caudospinosa	-0.483283019	36.30069997	2021/04/22	Apr-21	photo	search	1	BM41	BM41C	427
Agama caudospinosa	-0.495730983	36.30706502	2021/04/22	Apr-21	photo	search	1	BM42	BM42D	325
Trachylepis striata	-0.525785973	36.33567003	2021/04/22	Apr-21	sight	search	1	BP44	BP44A	396

Leptotyphlops merkeri	-0.522674024	36.331063	2021/04/22	Apr-21	voucher/photo	search	1	BN44	BN44B	430
Trioceros bitaeniatus	-0.995615032	36.59786803	2021/04/23	Apr-21	photo	search	1	CD70	CD70B	919
Duberria atriventris	-1.004153006	36.60389998	2021/04/23	Apr-21	voucher/tissue/photo	trap	1	CE70	CE70C	906
Mochlus sundevallii	-1.000800999	36.605715	2021/04/23	Apr-21	voucher/tissue/photo	search	1	CE70	CE70C	906
Acanthocercus gregorii	-1.000800999	36.605715	2021/04/23	Apr-21	photo	search	1	CE70	CE70C	906
Sclerophrys garmani	-1.039912971	36.59763099	2021/04/23	Apr-21	photo	trap	1	CD72	CD72D	904
Trioceros hoehnelii	-1.115123034	36.62039699	2021/04/23	Apr-21	photo	search	1	CF76	CF76C	90
Trioceros hoehnelii	-1.115015997	36.62041501	2021/04/23	Apr-21	photo	search	1	CF76	CF76C	90
Trioceros hoehnelii	-1.114992024	36.62042297	2021/04/23	Apr-21	photo	search	1	CF76	CF76C	90
Trioceros hoehnelii	-1.114967968	36.62043303	2021/04/23	Apr-21	photo	search	1	CF76	CF76C	90
Trioceros hoehnelii	-1.115236022	36.62038702	2021/04/23	Apr-21	photo	search	1	CF76	CF76C	90
Trachylepis megalura	-1.115236022	36.62038702	2021/04/23	Apr-21	photo	search	1	CF76	CF76C	90
Cacosternum plimptoni	-1.037350036	36.62629098	2021/04/23	Apr-21	sound-clip	search	5	CF72	CF72C	95
Cacosternum plimptoni	-1.036877967	36.62671099	2021/04/23	Apr-21	aural	search	100	CF72	CF72C	95
Cacosternum plimptoni	-1.036877967	36.62671099	2021/04/23	Apr-21	sound-clip	search	5	CF72	CF72C	95
Hyperolius viridiflavus ferniquei	-1.036877967	36.62671099	2021/04/23	Apr-21	aural	search	5	CF72	CF72C	95
Kassina senegalensis	-1.036877967	36.62671099	2021/04/23	Apr-21	sound-clip	search	5	CF72	CF72C	95
Ptychadena nilotica	-1.036877967	36.62671099	2021/04/23	Apr-21	sound-clip	search	5	CF72	CF72C	95
Phrynobatrachus keniensis	-1.036877967	36.62671099	2021/04/23	Apr-21	aural	search	5	CF72	CF72C	95
Cacosternum plimptoni	-0.90294	36.60135	2021/04/23	Apr-21	aural	incidental	20	CE65	CE65A	18
Cacosternum plimptoni	-0.89978	36.59843	2021/04/23	Apr-21	aural	incidental	20	CD64	CD64D	17
Cacosternum plimptoni	-0.88537	36.57912	2021/04/23	Apr-21	aural	incidental	20	CC64	CC64B	84
Cacosternum plimptoni	-0.88212	36.57472	2021/04/23	Apr-21	aural	incidental	20	CC63	CC63D	67
Cacosternum plimptoni	-0.88023	36.57165	2021/04/23	Apr-21	aural	incidental	20	CC63	CC63C	67
Cacosternum plimptoni	-0.88011	36.57185	2021/04/23	Apr-21	aural	incidental	20	CC63	CC63C	67
Cacosternum plimptoni	-0.87949	36.57013	2021/04/23	Apr-21	aural	incidental	20	CC63	CC63C	86
Trioceros hoehnelii	-0.79737	36.53437	2021/04/23	Apr-21	photo	incidental	1	CA59	CA59A	181
Trioceros hoehnelii	-0.79737	36.53437	2021/04/23	Apr-21	photo	incidental	1	CA59	CA59A	181
Trioceros hoehnelii	-0.79737	36.53437	2021/04/23	Apr-21	photo	incidental	1	CA59	CA59A	181
Trioceros hoehnelii	-0.79737	36.53437	2021/04/23	Apr-21	photo	incidental	1	CA59	CA59A	181
Ptychadena nilotica	-0.643264968	36.39405199	2021/04/23	Apr-21	sound-clip	search	10	BS50	BS50C	341

Phrynobatrachus keniensis	-0.643343003	36.39425701	2021/04/23	Apr-21	photo	search		BS50	BS50C	341
Agama caudospinosa	-0.619348967	36.39361697	2021/04/23	Apr-21	sight	search	1	BS49	BS49A	216
Acanthocercus gregorii	-0.573372971	36.37824104	2021/04/23	Apr-21	sight	search	1	BR46	BR46D	391
Leptotyphlops merkeri	-0.583898965	36.38472101	2021/04/23	Apr-21	voucher/photo	search	1	BR47	BR47B	335
Agama caudospinosa	-0.583576011	36.38493701	2021/04/23	Apr-21	sight	search	1	BR47	BR47B	335
Dasypeltis scabra	-0.583874993	36.38490197	2021/04/23	Apr-21	voucher/tissue/photo	search	1	BR47	BR47B	335
Trachylepis striata	-0.609986968	36.37581096	2021/04/23	Apr-21	sight	search	1	BR48	BR48C	388
Psammophis mossambicus	-0.610353006	36.378004	2021/04/23	Apr-21	sight	search	1	BR48	BR48D	338
Bitis arietans	-0.610500025	36.37802898	2021/04/23	Apr-21	photo	search	1	BR48	BR48D	338
Trioceros bitaeniatus	-0.70076298	36.43579898	2021/04/23	Apr-21	photo	search	1	BU53	BU53D	355
Bufonidae	-0.700466009	36.43610501	2021/04/23	Apr-21	sight	search	50	BU53	BU53D	355
Agama caudospinosa	-0.714624971	36.44899503	2021/04/23	Apr-21	sight	search	1	BV54	BV54D	104
Dasypeltis scabra	-0.714559006	36.44898204	2021/04/23	Apr-21	photo	search	1	BV54	BV54D	104
Tomopterna cryptotis	-1.039912971	36.59763099	2021/04/24	Apr-21	voucher/tissue/photo	trap	1	CD72	CD72D	904
Ptychadena sp. 1	-0.96523	36.64576	2021/04/24	Apr-21	photo	search	1	CG68	CG68C	7
Phrynobatrachus keniensis	-0.964802988	36.64528504	2021/04/24	Apr-21	voucher/tissue/photo	search	5	CG68	CG68C	7
Phrynobatrachus keniensis	-0.964777004	36.64523902	2021/04/24	Apr-21	photo	search	3	CG68	CG68C	7
Trioceros hoehnelii	-0.986582022	36.64872799	2021/04/24	Apr-21	photo	search	1	CG69	CG69D	4
Trioceros hoehnelii	-0.986436009	36.64831996	2021/04/24	Apr-21	photo	search	1	CG69	CG69D	4
Trioceros hoehnelii	-0.985584995	36.64718002	2021/04/24	Apr-21	photo	search	1	CG69	CG69D	4
Trioceros jacksonii jacksonii	-0.986163011	36.64727398	2021/04/24	Apr-21	photo	search	1	CG69	CG69D	4
Mertensophryne lonnbergi	-0.902305003	36.601416	2021/04/24	Apr-21	photo	search	2	CE65	CE65A	37
Mertensophryne lonnbergi	-0.90243903	36.601416	2021/04/24	Apr-21	voucher/tissue/photo	search	1	CE65	CE65A	37
Ptychadena mahnerti	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/tissue/photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	sound-clip	search	10	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/tissue/photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/tissue/photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/tissue/photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37

Cacosternum plimptoni	-0.902685961	36.601416	2021/04/24	Apr-21	photo	search	1	CE65	CE65A	37
Phrynobatrachus keniensis	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Phrynobatrachus keniensis	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Phrynobatrachus keniensis	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Phrynobatrachus keniensis	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Phrynobatrachus keniensis	-0.902685961	36.601416	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Phrynobatrachus keniensis	-0.902685961	36.601416	2021/04/24	Apr-21	photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.90237	36.60146	2021/04/24	Apr-21	sound-clip	search	20	CE65	CE65A	37
Trioceros jacksonii jacksonii	-0.90243903	36.601688	2021/04/24	Apr-21	photo	search	1	CE65	CE65A	37
Mertensophryne lonnbergi	-0.902685961	36.60183602	2021/04/24	Apr-21	sight	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.902685961	36.60183602	2021/04/24	Apr-21	voucher/photo	search	1	CE65	CE65A	37
Cacosternum plimptoni	-0.88689	36.58121	2021/04/24	Apr-21	aural	incidental	20	CC64	CC64B	100
Cacosternum plimptoni	-0.88217	36.57477	2021/04/24	Apr-21	aural	incidental	20	CC63	CC63D	67
Cacosternum plimptoni	-0.8816	36.57399	2021/04/24	Apr-21	aural	incidental	20	CC63	CC63C	67
Cacosternum plimptoni	-0.88032	36.57185	2021/04/24	Apr-21	aural	incidental	20	CC63	CC63C	67
Cacosternum plimptoni	-0.8795	36.57013	2021/04/24	Apr-21	aural	incidental	20	CC63	CC63C	86
Cacosternum plimptoni	-0.87233	36.55663	2021/04/24	Apr-21	aural	incidental	20	CB63	CB63B	182
Agama caudospinosa	-0.714764027	36.449061	2021/04/24	Apr-21	sight	search	1	BV54	BV54D	104
Leptotyphlops merkeri	-0.617016032	36.39044601	2021/04/24	Apr-21	photo	trap	1	BS49	BS49A	216
Agama caudospinosa	-0.616914025	36.38987797	2021/04/24	Apr-21	sight	search	2	BS49	BS49A	216
Agama caudospinosa	-0.616689976	36.389523	2021/04/24	Apr-21	sight	search	1	BS49	BS49A	216
Lygodactylus sp. 1 (*capensis*)	-0.615689009	36.38940196	2021/04/24	Apr-21	voucher/tissue/photo	search	1	BS49	BS49A	338
Lygodactylus sp. 1 (*capensis*)	-0.615689009	36.38940196	2021/04/24	Apr-21	tissue/photo	search	1	BS49	BS49A	338
Trioceros bitaeniatus	-0.615692027	36.389408	2021/04/24	Apr-21	photo	search	1	BS49	BS49A	338
Lygodactylus sp. 1 (*capensis*)	-0.615570992	36.38927498	2021/04/24	Apr-21	sight	search	1	BS49	BS49A	338
Trachylepis varia	-0.615872992	36.39075397	2021/04/24	Apr-21	sight	search	1	BS49	BS49A	216
Trachylepis striata	-0.608323999	36.37959103	2021/04/24	Apr-21	photo	search	1	BR48	BR48D	338
Agama caudospinosa	-0.61053196	36.38019998	2021/04/24	Apr-21	sight	search	1	BR48	BR48D	338
Agama caudospinosa	-0.617230022	36.38380503	2021/04/24	Apr-21	photo	search	1	BR49	BR49B	339
Agama caudospinosa	-0.617151987	36.38376002	2021/04/24	Apr-21	photo	search	4	BR49	BR49B	339
Agama caudospinosa	-0.617059032	36.38352499	2021/04/24	Apr-21	photo	search	1	BR49	BR49B	339

Agama caudospinosa	-0.617117034	36.38359297	2021/04/24	Apr-21	sight	search	1	BR49	BR49B	339
Agama caudospinosa	-0.617152993	36.38355198	2021/04/24	Apr-21	sight	search	1	BR49	BR49B	339
Trachylepis striata	-0.766640967	36.44837804	2021/04/24	Apr-21	sight	search	1	BV57	BV57C	945
Hemidactylus mabouia	-0.766623029	36.448586	2021/04/24	Apr-21	sight	search	1	BV57	BV57C	945
Acanthocercus gregorii	-0.77124699	36.449607	2021/04/24	Apr-21	photo	search	1	BV57	BV57D	946
Trachylepis striata	-0.771266017	36.44963097	2021/04/24	Apr-21	sight	search	1	BV57	BV57D	946
Trachylepis striata	-0.771255959	36.44967598	2021/04/24	Apr-21	photo	search	2	BV57	BV57D	946
Trachylepis striata	-0.771025959	36.44959501	2021/04/24	Apr-21	sight	search	3	BV57	BV57D	946
Lygodactylus sp. 1 (*capensis*)	-0.771197034	36.44979299	2021/04/24	Apr-21	photo	search	1	BV57	BV57D	946
Acanthocercus gregorii	-0.777098984	36.454426	2021/04/24	Apr-21	photo	search	1	BV58	BV58B	948
Trioceros bitaeniatus	-0.778034991	36.45427002	2021/04/24	Apr-21	photo	search	1	BV58	BV58B	948
Trioceros bitaeniatus	-0.778172035	36.45331699	2021/04/24	Apr-21	photo	search	1	BV58	BV58B	948
Psammophylax multisquamis	-0.77814999	36.45331398	2021/04/24	Apr-21	voucher/tissue/photo	search	1	BV58	BV58B	948
Acanthocercus gregorii	-0.77814999	36.45331398	2021/04/24	Apr-21	photo	search	1	BV58	BV58B	948
Aparallactus jacksoni	-0.801304998	36.46435998	2021/04/24	Apr-21	photo	search	1	BW59	BW59C	951
Acanthocercus gregorii	-0.825583013	36.46963396	2021/04/24	Apr-21	photo	search	1	BW60	BW60D	940
Bitis arietans	-0.91374496	36.51946002	2021/04/24	Apr-21	photo	search	1	BZ65	BZ65C	930
Acanthocercus gregorii	-0.860770997	36.48057704	2021/04/25	Apr-21	photo	search	1	BX62	BX62C	941
Duberria atriventris	-1.004153006	36.60389998	2021/04/25	Apr-21	photo	trap	1	CE70	CE70C	906
Hemidactylus squamulatus	-1.039912971	36.59763099	2021/04/25	Apr-21	voucher/photo	trap	1	CD72	CD72D	904
Lygodactylus sp. 1 (*capensis*)	-1.056194985	36.60289398	2021/04/25	Apr-21	photo	incidental	1	CE73	CE73C	917
Trachylepis striata	-1.061367961	36.60430198	2021/04/25	Apr-21	photo	incidental	1	CE73	CE73C	917
Trioceros hoehnelii	-1.062106993	36.61113298	2021/04/25	Apr-21	photo	search	1	CE73	CE73D	918
Trioceros hoehnelii	-1.062155021	36.61114002	2021/04/25	Apr-21	photo	search	1	CE73	CE73D	918
Ptychadena nilotica	-1.06193	36.61121	2021/04/25	Apr-21	sight	search	1	CE73	CE73D	918
Trioceros hoehnelii	-1.072817976	36.62679699	2021/04/25	Apr-21	photo	search	1	CF74	CF74C	92
Trioceros hoehnelii	-1.072817976	36.62679699	2021/04/25	Apr-21	photo	search	1	CF74	CF74C	92
Cacosternum plimptoni	-1.10174099	36.63050196	2021/04/25	Apr-21	aural	search	10	CF76	CF76B	89
Cacosternum plimptoni	-1.101673013	36.63083699	2021/04/25	Apr-21	sound-clip	search	10	CF76	CF76B	89
Phrynobatrachus keniensis	-0.66254301	36.40217699	2021/04/25	Apr-21	photo	trap	1	BS51	BS51D	358
Duberria atriventris	-0.662419964	36.40211103	2021/04/25	Apr-21	photo	trap	1	BS51	BS51D	358

Psammophylax multisquamis	-0.742623964	36.46005596	2021/04/25	Apr-21	photo	search	1	BW56	BW56A	348
Lygodactylus sp. 1 (capensis)	-0.741614029	36.45921199	2021/04/25	Apr-21	photo	search	1	BW56	BW56A	348
Acanthocercus gregorii	-0.741606988	36.45920402	2021/04/25	Apr-21	sight	search	1	BW56	BW56A	348
Acanthocercus gregorii	-0.755631002	36.47519502	2021/04/25	Apr-21	photo	search	1	BW56	BW56D	349
Lygodactylus sp. 1 (capensis)	-0.763816014	36.48890203	2021/04/25	Apr-21	photo	search	1	BX57	BX57B	442
Trachylepis striata	-0.762000997	36.48962799	2021/04/25	Apr-21	sight	search	1	BX57	BX57B	442
Trioceros hoehnelii	-0.762023963	36.48903002	2021/04/25	Apr-21	photo	search	1	BX57	BX57B	442
Trioceros hoehnelii	-0.763531029	36.48906204	2021/04/25	Apr-21	photo	search	1	BX57	BX57B	442
Trioceros hoehnelii	-0.790027985	36.51812403	2021/04/25	Apr-21	photo	search	1	BZ58	BZ58C	121
Acanthocercus gregorii	-0.792557979	36.51714896	2021/04/25	Apr-21	photo	search	1	BZ59	BZ59A	121
Trioceros hoehnelii	-0.792578012	36.51706799	2021/04/25	Apr-21	photo	search	1	BZ59	BZ59A	121
Acanthocercus gregorii	-0.792100998	36.51718098	2021/04/25	Apr-21	photo	search	1	BZ59	BZ59A	121
Trioceros hoehnelii	-0.813506031	36.53650604	2021/04/25	Apr-21	photo	search	1	CA60	CA60A	129
Trachylepis varia	-0.813580966	36.53640403	2021/04/25	Apr-21	photo	search	1	CA60	CA60A	129
Cacosternum plimptoni	-0.812861966	36.53765503	2021/04/25	Apr-21	photo/sound-clip	search	1	CA60	CA60A	129
Trioceros hoehnelii	-0.848600976	36.54060697	2021/04/25	Apr-21	photo	search	1	CA62	CA62B	124
Trioceros hoehnelii	-0.848673983	36.54146796	2021/04/25	Apr-21	photo	search	1	CA62	CA62B	124
Cacosternum plimptoni	-0.849782992	36.54795899	2021/04/25	Apr-21	aural	incidental	10	CB62	CB62A	154
Trioceros hoehnelii	-0.855112039	36.55057901	2021/04/25	Apr-21	photo	search	1	CB62	CB62A	154
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