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NAIROBI-NAKURU-MAU SUMMIT HIGHWAY PROJECT

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

KENYA - APPENDICES 6-18 TO 6-25

WSP REF.: 201-10312-00

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APPENDIX

6-18 *BIODIVERSITY BASELINE INVESTIGATION – MAMMALS*

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

BIODIVERSITY BASELINE INVESTIGATION
Mammals
FINAL REPORT

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Document history

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Nairobi-Nakuru-Mau Summit Highway Project
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BIODIVERSITY BASELINE INVESTIGATION
MAMMALS

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 Projectt. 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:

- Mammals

This work was undertaken by the following team members:

- Team leader: Alain Thomas
  - Degrees: Diploma (Category III) of Occupational Studies in Agriculture, specialised in Forest production and wood marketing
  - Professional accreditation: NA
  - Number of years of experience: 22
  - Number of publications in the field if relevant: 3
  - Prior experience in the country or region: East Africa (Ethiopia, Burundi, Rwanda)

- Assistant 1: Phoebe Mottram
  - Degrees: M.Sc. Conservation Biology, B.Sc. (hons) Geography
  - Professional accreditation: SACNASP Candidate Natural Scientist
  - Number of years of experience: 3
  - Number of scientific publications in the field: 1
  - Prior experience in the country or region: NA

- Assistant 2: Jerome Gaugris
  - Degrees: PhD and MSc in Wildlife Management
  - Professional accreditation: SACNASP Professional Scientist
  - Number of years of experience: 21
  - Number of publications in the field: 26

- Prior experience in the country or region — East Africa (Burundi, Rwanda, Uganda, Ethiopia, Tanzania and Kenya)

2 INTRODUCTION

This report presents the summary of the mammalian fauna inventory conducted in the project's Biodiversity Local Assessment Area, a study area which covered 2 km either side of the A8 Highway, the focus road of this study. Field investigations were conducted from February 17 to 26, 2021 and April 14 to 25, 2021. This work totalled 22 full days of field survey work.

This work's main purpose is the inventory of mammal species and the characterization of mammalian fauna present and the evaluation of the impact of the project

All types of existing environments in the study area have been surveyed, with particular attention to forest environments and natural or semi-natural savannahs. The private conservation areas of Soysambu Conservancy and Marula Estates were also covered. These environments, which are the most natural in the study area, are on the one hand the most likely to harbour interesting fauna and on the other hand most likely to be negatively affected by any environmental impacts of the project.

Beyond the general inventory of mammalian fauna, species with an unfavourable conservation status recognized internationally and listed in the IUCN Red Book of Threatened Species (IUCN) in the categories CR (critical danger of extinction), EN (endangered), VU (vulnerable), NT (near threatened) were sought.

3 STUDY AREA

3.1 Location and general description

The study area is located in central-western Kenya. Starting around 40km north-west of Nairobi, it is situated in both the Kiambu and Nakuru Districts, with the majority located in the latter.

The study area corresponds to project's Biodiversity Local Assessment Area, which includes a 2 km buffer on either side of A8 and A8 South Highways, totalling an entire study area of more than 93,000 ha. The altitude of the study area varies from 1,700 to about 2,700 metres, with two areas located in the afro-montane area at its northern and southern extremities.

Within the landscape, 5 zones can be distinguished (Figure 1, Figure 2):

Zone 1)
Located in the north, an area of altitude largely dominated by an agricultural matrix and by plantations of exotic species (Eucalyptus, resinous etc). Natural forest elements, most often subject to high exploitation pressure (domestic uses), are present however they are located almost exclusively in valleys. There are also large areas of highly grazed grasslands. On the eastern flank (towards Nakuru) of this mountainous area, there is a transitional zone where landscapes comprised of forests and forested meadows with Acacias are found.
The potential natural habitats in Zone 1 are:

- Afromontane undifferentiated forest (the vast majority);
- Edaphic wooded grassland;
- Evergreen and semi evergreen bushland and thicket (at the transition to zone 2).

Zone 2)
To the west of Nakuru, a vast and highly agricultural plain, where natural or semi-natural environments are almost excluded. This area has a rather heterogeneous composition and contains a mosaic of crops, pastures and forest plantations interspersed with small farms and larger estates.
The potential natural habitats in Zone 2 are:

- Afromontane undifferentiated forest (in the centre);

- Upper acacia wooded grassland (which forms the lower part of the transition with zone 1);
- Evergreen and semi evergreen bushland and thicket (especially to the east of this area and which is occupied today by the settlement of Nakuru).

Zone 3)
Between Nakuru and Naivasha, there is a vast plain also characterised by agriculture and the presence of several urban areas. However, major natural elements are found with Lake Elmentaita and large areas of thicket and degraded woodland on the slopes of the steepest hills. Well-formed woodlands are often found along the banks of major streams and open to wooded savannahs. Two conservation areas are located in this area, Soysambu Conservancy, located north of Elmentaita Lake and Marula Estates located just north of the city of Naivasha. Agriculture and grazing are practised in these private conservation areas, but very large natural or semi-natural environments are also present.
The main potential natural habitats in Zone 3 are:
- Evergreen and semi evergreen bushland and thicket (covering almost all of this zone);
- Riverine wooded vegetation on the outskirts of Lakes Elmentaita and Naivasha (particularly well-established patches of which remain in the Soysambu Conservancy);
- Afromontane undifferentiated forest (along some of the eastern edge of the area).

Zone 4)
South of Naivasha, by the A8 South Highway, is a plateau comprising pastures with relatively little cultivated area. It is bordered to the west by the Longonot Volcano National Park and dense woodlands. To the east and south this area is bordered by a transitional zone comprising the mountainous southern part of the study area (Zone 5). To the east, the landscape is heavily transformed and is similar to that located to the north of the study area (Zone 1). To the south, on the other hand, more natural vegetation is found on the escarpment of the Rift valley.
The main potential natural habitats in Zone 3 are:
- Evergreen and semi evergreen bushland and thicket (for 3/4 of this zone) ;
- Afromontane undifferentiated forest (for part of the eastern edge of the area).

Zone 5)
The south of the study area has an Afromontane character with a large proportion of the land covered by natural landscapes. While agricultural land and pasture are present, areas of natural or sub-natural forests are better represented. This trend is particularly evident at the eastern limit of the study area, bordering the Kinale Forest. At the A88, an escarpment marks the transition from the Naivasha Plateau (Zone 4) to the mountain, this area is occupied by dense mountainside woodlands and a few well-structured acacia forests. Overall, on the west side of this area, there is a continuum of relatively well-preserved environments at the Rift Valley.
The main potential natural habitats in Zone 5 are:
- Afromontane undifferentiated forest (for some of the eastern edge of the area);
- Afromontane bamboo;
- Edaphic wooded grassland;
- Afromontane rain forest (at the extreme eastern edge of this area).

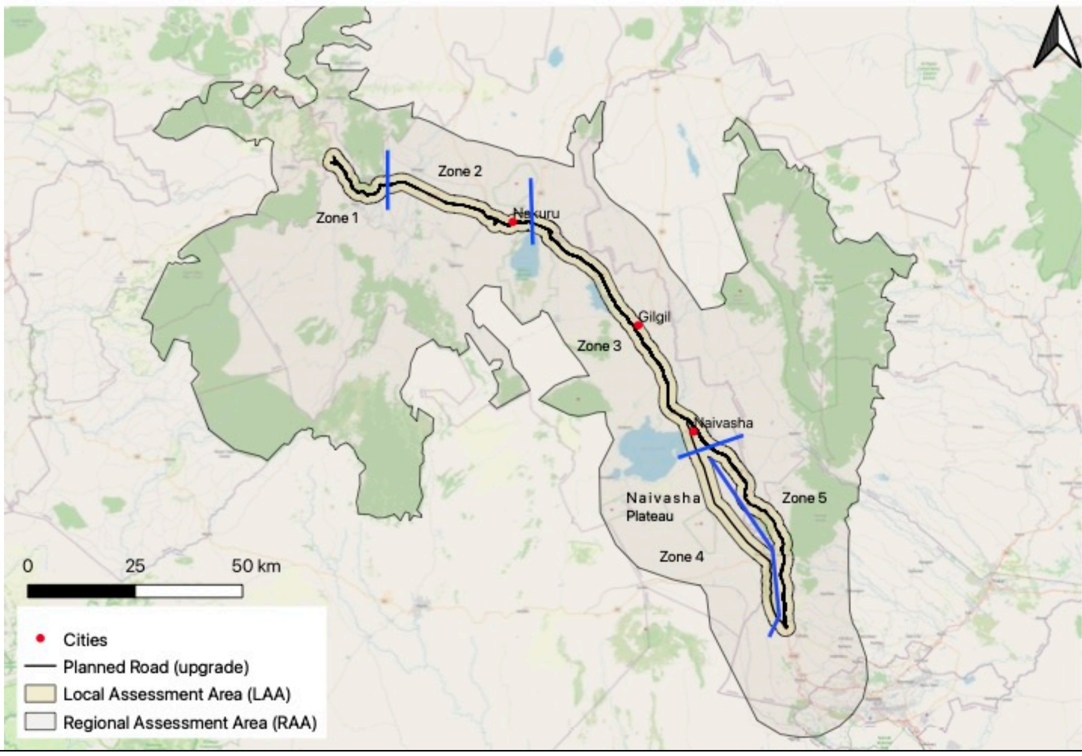


Figure 1: The larger landscape zones of the study area.

	
Agricultural landscape matrix (zone 5)	*Eucalyptus* plantation (zone 1)
	
Acacia woodland (transition between zones 1 and 2)	Landscape of thickets and woodlands in the hills overlooking Lake Elmentaita (zone 3)
	
Acacia savannah in Soysambu Conservancy (zone 3)	Afromontane Forest (eastern edges of zone 5)
	
The southern shores of Lake Elmentaita (zone 3)	The grasslands of the Naivasha plateau (zone 4)

Figure 2: Landscapes of the study area

4 METHODS

4.1 Active searching for presence indices and direct observations at sampling points

The mammalian fauna inventory was carried out in parallel with a larger analysis of the composition of flora and fauna of the study area. Active searching for tracks and signs indicating mammal presence and direct observations were carried out at a selection of points chosen from the sampling plan provided to all FFMES teams. This plan was put in place to organize surveys and facilitate the cross-reference of data from different taxonomic groups. An indicative mapping of potential original natural habitats was carried out prior to the field surveys and served as a framework for the location of terrestrial wildlife sampling points. Depending on the configuration of the land or the state of habitat conservation, points could be identified to complement or replace those points from the initial sampling plan. Each point (3 to 5 ha) was surveyed on foot, for about 30 minutes with some variability depending on the richness of the site.

4.2 Direct observations by road

For the Soysambu Conservancy and Marula Estates conservation areas, as well as for the plateau south of Naivasha, observations were recorded while travelling along roads. Different routes were travelled by car at low speeds and any observed mammals were geolocated by GPS point. Counts of the number of individuals of each species present was recorded. Where possible, when the conservation areas were returned to, alternative roads were driven on in order to cover as large an area as possible.

4.3 Camera trapping

A major camera trapping effort was undertaken in the study area. A total of 100 camera traps were deployed initially, from five different brands (Dörr, Denver, Bushnell, Spypoint and Vosker). These automatic motion-detection cameras allow for species to be recorded 24 hours a day, with images taken in both the daytime and the nightime. The detection distance varies from 10 to 20 metres depending on the model and the environmental conditions (i.e. outside temperature). As the study progressed, a total of 5 cameras from the short-term camera trapping effort were removed due to theft while another camera ceased to function. For the long-term camera trapping effort, by the end of May 2021, 9 units were considered as lost, one was vandalized and one got dammaged by battery leakage..

4.3.1 Long-term camera trapping

A set of 50 camera traps with GSM transmission was used for a long-term camera trapping effort of three months. These cameras were deployed during the first survey period in February 2021 and data was gathered until the end of May. .

This technique was primarily used to understand the movement of the giraffes (*Giraffa camelopardalis ssp camelopardalis* and *sp tippelskirchi*). The scarcity of this taxon and its unfavourable conservation status on a global scale justified the application of this sampling method. Long term camera traps were placed in habitats where giraffes were the known to be present (or there was potential for presence), namely the Soysambu Conservancy (*ssp camelopardalis*) and Marula Estates conservation areas (*ssp tippelskirchi*).

The cameras were set to automatically take images every 15 minutes. In addition, the movement-detection trigger function remained active throughout. To improve the chances of capturing giraffe images, the traps were positioned in such a way to have the widest possible range and shooting field. There were multiple technical issues, two cameras were stolen and a further two damaged by wildlife and domestic animals, yet still a total of 3,342 trap nights were recorded.

A total of XX photographs were transmitted for XX "mammalian events". The processing of the images was the object of an automatic first analysis and then a verification by a member of the team for validation of the data. “Wild ID” software was used for automated processing.

4.3.2 Short-term camera trapping

Another set of 50 camera traps was used for the general detection of mammals, over the entire study area. Small and medium-sized mammals were targeted by this set of camera traps. To best cover the study area and all types of landscapes and habitats, the traps were arranged in clusters of five (initially) for periods of deployment in a location ranging in duration from three to five days. The clusters of five units were deployed as a loose trapping grid within 100 m of a predetermined sampling location to ensure the coverage of the sampling location in enough details and maximise chances of picking up species of relevance for the site. As the study unfolded and units were removed due to theft of functionality loss, some clusters of four units were deployed.

A total of five traps were stolen in February and one unit became defective. The traps were set in photographic mode and three images were taken with each movement detection. A time interval of 5 sconds was used to separate consecutive events.

4.4 Small mammal trapping

Initially, non-lethal sampling of small mammals using "Sherman" traps was attempted using a set of 120 Sherman traps. The initial deployment approach called for a total of 3 Lines of 40 baited (peanut butter and seeds) sherman traps each were placed in three separate locations for three successive nights for each line. However, the theft of 52 sherman traps and the destruction of 28 others by a troop of Olive Baboons led to the suspension of the sherman trap-based operation during the February survey period. Based on available local alternatives, lethal trapping was then used as an alternative towards the end of the first survey period and during the April field survey. A set of 35 snap traps was purchased and used during the second half of the february field season, while a set of 120 snap traps was deployed during the second field season of April. The deployment was based on the planned approach contemplated for Sherman traps, with 3 lines of 40 traps each. Traps were baited with small balls of paste made from peanut butter mixed with oats and shredded wheat.

4.5 Additional data

Supplementary data were provided by team members working on other taxa. Notably the herpetology team provided data regarding small mammals which were incidentally captured in their trapping devices.

4.6 Data analysis

4.6.1 Species accumulation curves

Only taxa identified to the species level (or the genus level where uncertainty was only between two species) were incorporated into the species accumulation curves. Taxa only identified to the family level were not included (e.g. *Crocidura* sp., *Canis* sp. etc.).

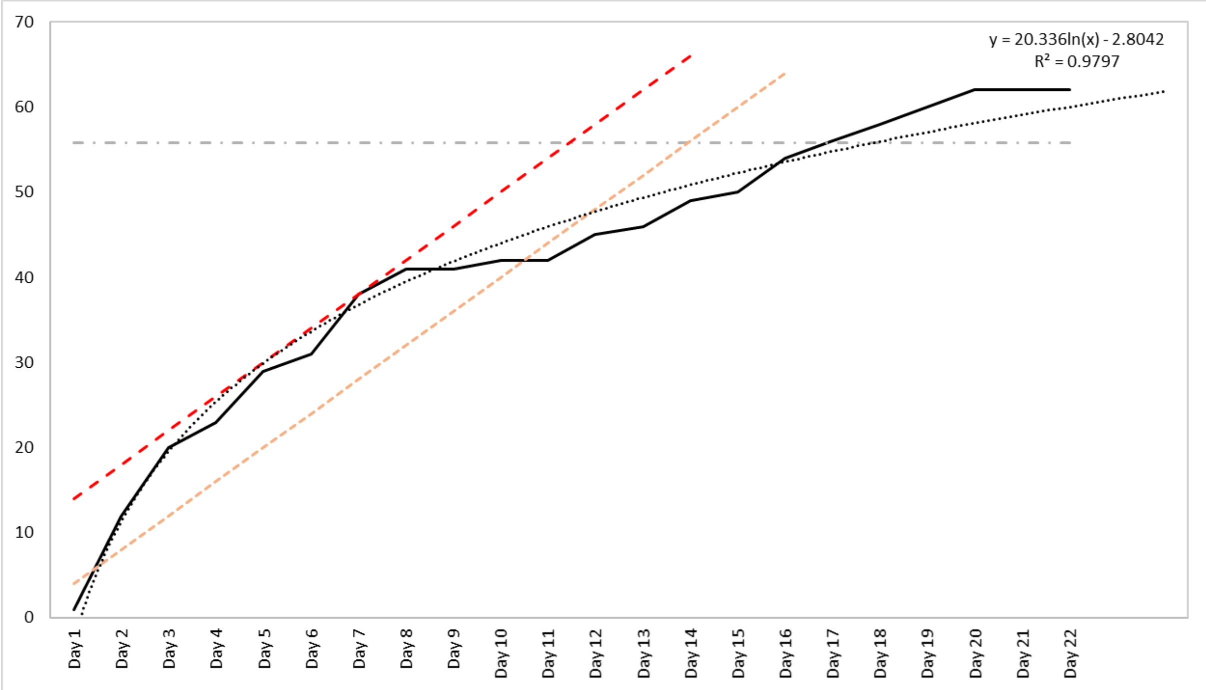
a)

b)

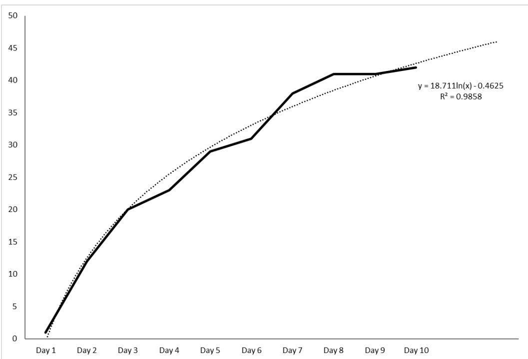
c)

d)

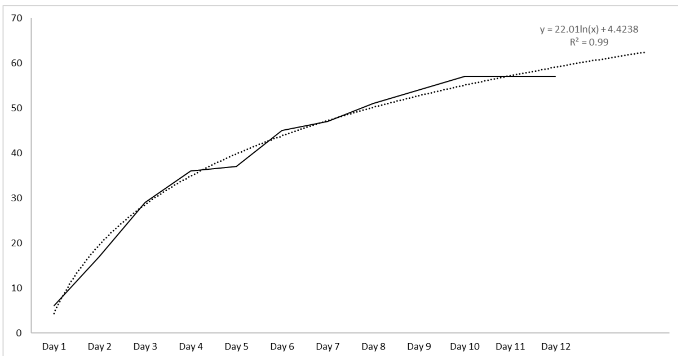
Figure 3: Examples of the collection methods used during the mammal survey: a) Direct observation of a plains zebra (*Equus quagga*) from the road, b) position of a lethal trap for small mammal capture, c) a Dörr camera trap in place for short term observation of three to five days, d) Syke's monkey (*Cercopithecus albogularis*) captured by a camera trap.



a) Mammal species accumulation curve for both survey periods, the grey stippled line highlights the point where 90% of the species sampled was met, the orange stippled line highlights the species accumulation pattern assuming 4 methods are combined and each method yields 1 species per day, while the red stippled line is an adjusted version of the orange stippled line to evaluate where the 1 species per day per technique combined approach is tangent to the actual species accumulation curve for the study. The black dotted line is a trendline fitted to the actual species accumulation curve to evaluate the fit of actual data (R^2 value) to a theoretical prediction curve. The prediction curve was extended by two periods to evaluate whether the predicted pattern tapers off or continues to grow. The actual species accumulation pattern curve shape is well explained by the predictive pattern (fit is close to 98%) while the point where 90% of species sampled for the study period is situated at approximately 17 days, hence highlighting that the study effort period was adequate, a fact further confirmed by the parallel shape of the actual species accumulation curve and the 90% limit over two work days after that point. The point where the actual species accumulation curve pattern drops below a theoretical 1 species accumulated per day lies at approximately 5 days of work.



b) February - Mammal species accumulation curve



c) April - Mammal species accumulation curve

Figure 4: Mammal species accumulation curves for the study period and the two seasons of work.

4.6.2 Analytical process 1 - Active search for presence indices and direct observations by sampling point

Ninety-six points were surveyed by the mammal team (42 in February, 54 in April and four in both missions), 301 points of raw data were collected, and 29 species recorded. This method was used mostly outside the Soysambu Conservancy and Marula Estates conservation areas, the vast majority were in locations subject to strong human pressure. The number of direct observations is less than what was obtained by observation from roads. The sampling point method has been shown to be effective in improving the identification of the presence of small carnivores (100 raw data), this presents functionally interesting data, however, it is often not possible to identify the exact species which left the track or sign.

4.6.3 Analytical process 2 - Direct observations by road

This method was applied to the Soysambu Conservancy and Marula Estates conservation areas, a small natural area on the eastern shore of Lake Naivasha, and the plateau prairies further south of Naivasha. This method was effective in assessing the numbers and geographical range of large and medium-bodied herbivores.

Three routes were followed in Soysambu Conservancy, four in Marula Estates and four on the plateau south of Naivasha, covering about 12,800 ha (2700 ha in Soysambu Conservancy, 6700 ha in Marula Estates, 3400 ha south plateau). In total, 318 points of mammal presence were noted (115 in February and 173 in April). From 336 records, a total of 26 species and 5257 individuals were recorded.

4.6.4 Analytical process 3 – Short-term camera trapping

In the combined two survey periods, a total of 45 sampling locations were sampled for a total of 638 trap nights. A total of 140,000 photographs were taken and a total of 372 validated "mammal events" (258 in February and 114 in April) relating to 38 species were recorded. This made camera trapping the most effective method for species-specific detection. They are particularly useful for medium to small species and carnivores. Ten species were only recorded by the camera traps, for example: white-tailed mongoose (*Ichneumia albicauda*), zorilla (*Ictonyx striatus*), bohor reedbuck (*Redunca bohor*) and serval (*Leptailurus serval*).

4.6.5 Analytical process 4 - Small mammal trapping

A total of six sampling locations for a total of 299 trap nights were sampled with Sherman traps and 12 sampling locations for a total of 1,269 trap nights were sampled with the snap traps. A total of twelve species were recorded from a total of 59 individuals captured. In February, issues associated with theft and destuction of the traps allowed for the capture of only 20 individuals from six species. In April, 39 individuals were captured from nine species. The catch rate was 5.54 animals per 100 trap nights in February and 3.23 in April.

4.6.6 Analytical process 5 - Additional data

Additional data was provided by the herpetology and ornithology teams. Their findings totalled 86 data points, for 27 species and 123 individuals. Pitfall trapping, used by the herpetology team, allowed for the capture of 23 small mammals. (12 Crossidura sp, two Lemniscomys striatus, three Mus minutoides, four Mus triton, one Dendromus insignis and one Dendromus messorius). The records of Dendromus insignis and Mus triton were the only records taken during the entire field survey. The contribution of the data from the herpetology team became particularly valuable when the use of Sherman traps by the mammal team had to be halted and large rodent snap traps had to be used instead. These lethal traps were of such a size that they reduced the potential catch of smaller mammals and thus small mammals were distinctly under-represented in the mammal team's data collection.

4.6.7 IUCN Listed species or species with special status

Nine species on the IUCN World Red List of Threatened Species were observed during the field surveys in February and April 2021, their records totaled 183 contact points from 1,795 individuals.

1. African Savanna Elephant (*Loxodonta africana*) EN

2. Fringe-eared Oryx (*Oryx callotis*) EN
3. Giraffe (*Giraffa camelopardalis*) VU (Masai *ssp tippelskerki* EN / Nubian *ssp Camelopardalis* CR)
4. Leopard (*Panthera pardus*) VU
5. Common Hippopotamus (*Hippopotamus amphibious*) VU
6. Plains Zebra (*Equus quagga*) NT
7. Cape Buffalo (*Syncerus caffer*) NT
8. African Clawless Otter (*Aonyx capensis*) NT
9. Striped hyena (*Hyaena hyaena*) NT

One taxon of rodent captured during the field surveys is classified to the species level (Margaret's Brush-furred Rat (*Lophuromys margarettae*)) by Wilson and Mittermeier's (2009) "Handbook of the Mammals of the World". However, this species is not listed on the IUCN's Red List, it is instead incorporated into the Yellow-spotted Brush-furred Rat (*Lophuromys flavopunctatus*) which is listed as 'Least Concern'. Despite this, the presence of this species in the study area is interesting. Margaret's Brush-furred Rat is belived to be potentially threatened by habitat alteration, particularly that which includes the use of fire (Taylor, 2017).

5 RESULTS

5.1 Sampling sufficiency and species accumulation curves

5.1.1 <u>Spatial sampling overview – overall results</u>

A total of 241 km^2, or 20% of the study area was sampled as part of the mammal survey. Areas at higher altitudes, where afromontane habitats appear to be naturally occuring, covered 54 km^2 (24 km^2 in zone 1 and 30 km^2 in zone 5) and the remaining 187 km^2 was located in the average elevation area of zones 2 to 4.

There is a certain heterogeneity in the spatial distribution of sampling. Apart from the afromontane areas, there were four particularly well surveyed areas:

- the Soysambu Conservation Area / Lake Elmentaita (Zone 3);
- the Marula Estates Conservation Area (Zone 3);
- grassy plateau south of Naivasha (zone 4);
- the western foothills of the southern afromontane zone (zone 4).

The un-surveyed gaps are mainly due to the exclusion of the urban areas of Nakuru to the north, Gilgil between Soysambu Conservancy and Marula Estates and Naisvasha in the south, and the mostly transformed land bordering them. Indeed, the urban areas were considered of limited interest as impact is already severe and habitat is already modified or transformed, a situation unlikely to be made significantly worse by the road development. Moreover, agricultural areas, where natural habitats have been replaced by crops, with a high density of dwellings were infrequently visited due to the low probability of finding presence of an important or remarkable mammal species. This type of landscape is found mainly in high altitudes and foothills. This is the case for example in the southern part of the Nairobi / Mau road (zone 5) but also in the plains in Zone 2.

The relative exclusion of these environments is also explained by the need, in the limited time of the two survey periods, to ensure a satisfactory level of sampling in the parts of the study area considered to be at greatest risk. As a result, a significant portion of the sampling effort focused on the Soysambu Conservancy and Marula Estates conservation areas. This is also the case for parts of the afromontane areas, including the "southern foothills". The grassland plateau south of Naivasha, where a significant presence of large mammals was detected, required more effort than was initally predicted, necessitating a reduction in the level of sampling of more degraded areas (towards the southern end of Zone 5).

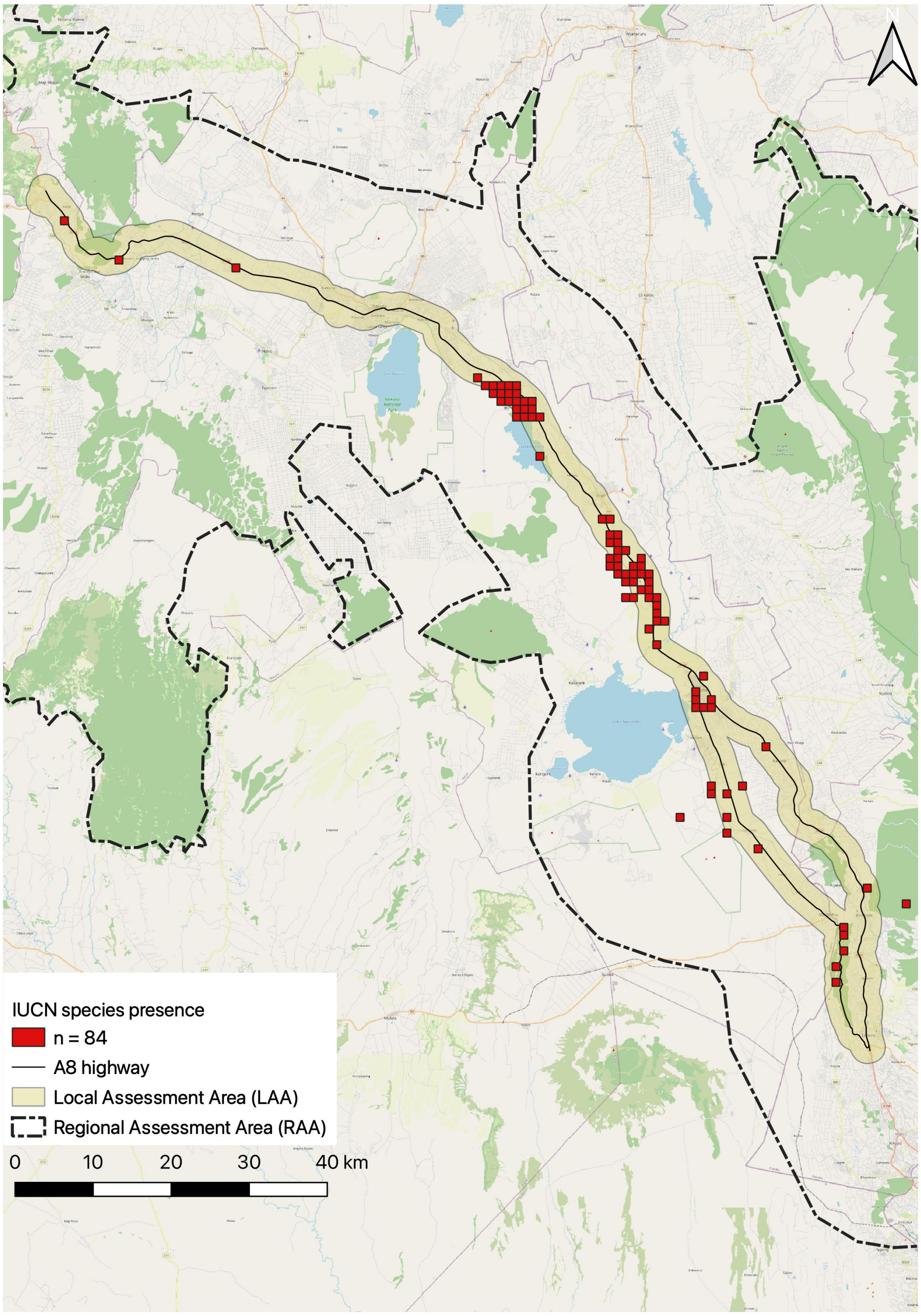


Figure 5: Distribution of data points recorded for mammal species listed on the IUCN Red List of Threatened Species.

Table 1: Distribution of sampling effort and data by natural vegetation types		
Potential vegetation in the 2km buffer around the planned road	Squares (1 km²) sampled in the 2 km buffer, divided by "habitat potential" zone (nb tt - 241)	Total number of mammal data records (nb tt-1170) per "potential habitat" zone
Afromontane bamboo	12 (5%)	20 (1.7%)
Afromontane rainforest	5 (2%)	2 (0.2%)
Afromontane undifferentiated forest	78 (32%)	139 (11.9%)
Edaphic wooded grassland	2 (1%)	0
Evergreen and semi evergreen bushland and thicket	176 (73%)	726 (62%)
Freshwater swamp	15 (6%)	0
Helophytic vegetation	8 (3 %)	22 (1.9%)
Riverine wooded vegetation	44 (18%)	216 (18.5%)
Upper acacia wooded grassland	7 (3%)	38 (3.2%)
Water	16 (7%)	1 (0.1%)

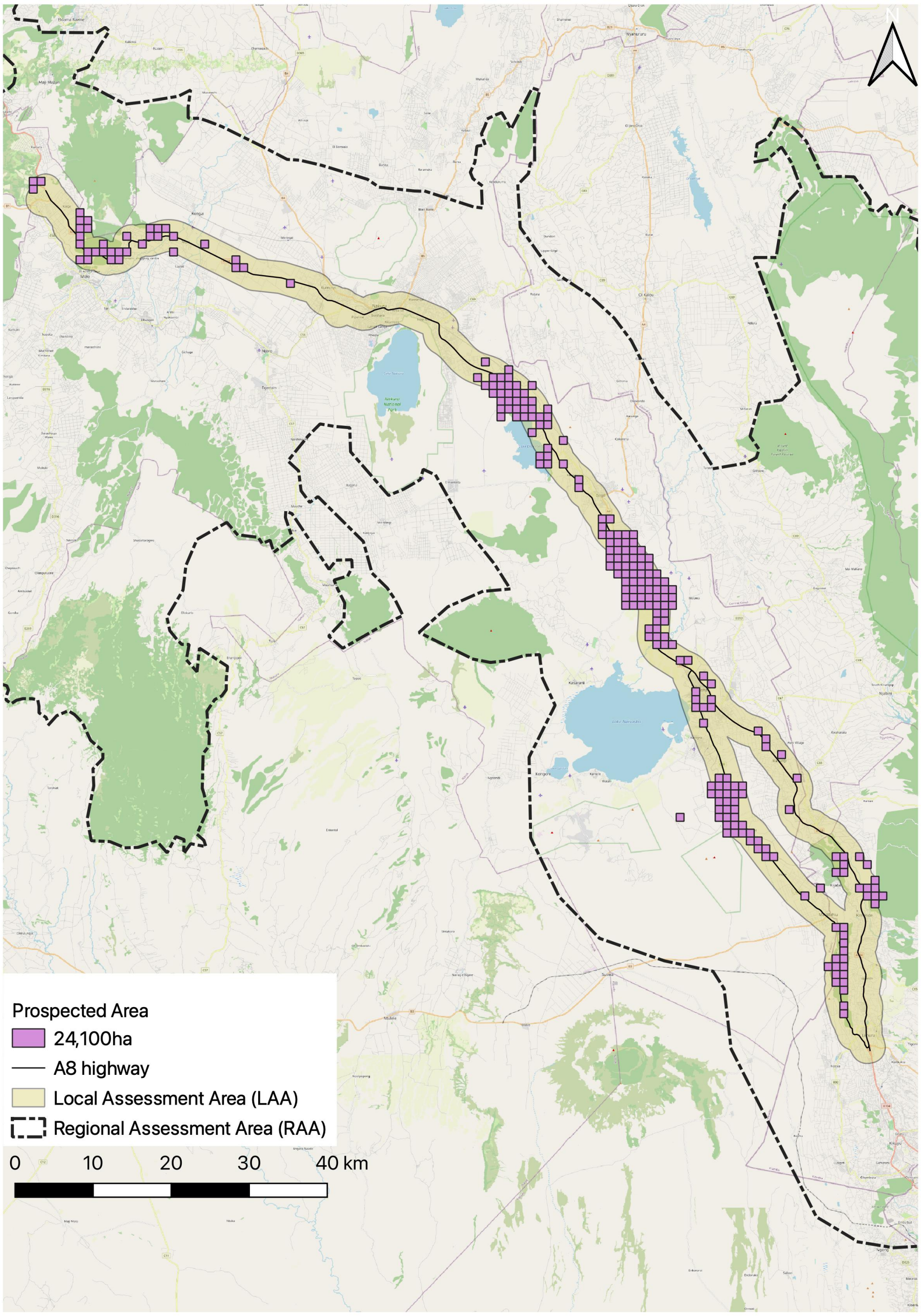


Figure 6: Coverage of the sampling effort for mammals. 241 km² were covered, or 20% of the study area.

a) c) b)

Figure 7: Distribution of trapping systems used for mammal sampling.

5.1.2 Species accumulation curves for the study area – overall results

The overall accumulation curve appears to show a cap on the accumulation of new species from the 21st field sampling day. It can therefore be reasonably estimated that the level of detection of the specific mammal species richness of the study area is reliable and representative for the seasons sampled as well as the study.

A total of 64 species were noted in the study area, 45 during the February 2021 survey period and 60 in April 2021. Four species were noted only in February 2021 and 19 were noted only in April 2021. These results are explained by the greater success in small mammal trapping in April (including data provided by the herpetology team) and by data from the short-term camera trapping in the agricultural matrix, which provided information on a different group of species than the first season focused on the conservation areas.

5.2 Analytical process 1 results – Active search for presence indices and direct observations by sampling point

This method was used mainly in the afromontane areas of the north and south of the study area as well as in degraded and rural landscapes. It required a lot of effort in terms of logistics (i.e. movement/time-to-exploration ratio). With 301 data points obtained, the sampling results can be considered good yet not exceptional. In particular, few direct observations were made and thus the proportion of presence indices recorded is important. This explains a low level of identifications to the species level (64%).

However, the number of data obtained is still small in terms of the effort, which can be weighed by the degree of degradation and the invasive nature the sampling method on the mammal fauna in question.

5.3 Analytical process 2 results – Direct observations by road

This method is well adapted to open landscapes easily accessible by vehicle or traversed by a network of roads. It allows for an understanding of the presence and precise location of mammalian fauna in an area. It is mainly suitable for medium to large-sized species and is ineffective for detecting small species. The survey and logistical effort was less than that of Analytical Process 1, yet provided an equivalent amount of data (336 points). The identification rate for species was much better (95%).

This method provides a means of obtaining important data on conservation areas, including the plateau south of Naivasha. This data also covers large species with a strong displacement capacity and a risk of crossing the road (therefore with an increased risk of collisions with vehicles). This method also allowed for the collection of data regarding species listed on the IUCN Red List of Threatened Species (57% of zebra records, 35% of giraffe records and 50% of buffalo records).

5.4 Analytical process 3 results – Short-term camera trapping

This was an important method which greatly enriched the database. The required sampling effort was increased by the short duration of the surveys and by the configuration of the study area which required the frequent removal of camera trap clusters. The trapping time per site of three to five days is considered very short for this kind of technique. Nevertheless, the results were positive. Quantitative distribution of data supports the results of Analytical process 1 with little data in afromontane areas compared to lower-altitude areas.

5.5 Analytical process 4 results - Small mammal trapping

This method required the greatest field effort when compared to the the volume of data generated. However, it remained essential to properly integrate small mammals into the inventory. Significant difficulties were encountered with this method specifically relating to the theft and destruction of a large number of Sherman traps during the first field survey. This led to the cessation of Sherman trap deployment for several days in February and the use of lethal traps in April. However, the type of lethal traps available in the local markets were of large size and unsuitable for the capture of small species (i.e. those of the genus *Dendromus* or *Mus* among others). Thus, it is likely the use of these traps led to a bias in the results.

6 DISCUSSION

6.1 Species accumulation curves and sampling efficiency

With 64 species noted and a species accumulation curve that appears to reach a plateau at the end of the second field survey we can consider that the data collected provides a mammalian fauna composition that is representative of the study area and the seasons sampled. This data therefore provides a reliable means of analysing the impact of the road expansion project. The information provided here covers both the road and its 2 km buffer zone but can also be considered as representative of the entire region.

However, although it is considered representative for both seasons and the study area, this inventory is deemed as not complete. The main gaps to be considered are at the small mammal level. The total of 12 species recorded over both field surveys is below the expected total of small mammal species present in the region. It is possible that nearly 20 species of rodents remain to be found (Musila *et al.*, 2019). For shrews, the same is true. Eleven *Crocidura sp.* were captured from probably two to three different species. However, due to the great difficulty of identification in the field (the animals have not been kept) the records only show the genus level. Fourteen species of the genus *Crossidura*, two species of the genus *Suncus* and one species of the genus *Sylvisorex* are likely to be found in the region (Musila *et al*., 2019).

Finally, data from mammal counts in the Soysambu Conservancy and Marula Estates conservation areas (between 2014 and 2018) mention several species that we did not record in the study:

- Lesser Kudu (*Traglaphus imberbis)* (LC);
- Klipspringer (*Oereotragus oreotragus)* (LC) / Masai Klipspringer (*Oreotragus schillingsi*) (Handbook Mammals of the World "HMW");
- Oribi (*Ourebia ourebi)* (LC) / Central Oribi (*Ourebia hastat*) (HMW);
- Caracal (*Caracal caracal*) (LC);
- Cheetah (*Acinonyx jubatus*) (VU);
- Lion (*Panthera leo*) (VU);
- African Wolf (*Canis lupaster*) (LC);
- Side-striped Jackal (*Canis adustus*) (LC).

The fixed camera trap record remaisn to be incorporated to the present overview and Lion has been noted on at least one occasion, which would improve the overall results.

6.2 Species of conservation concern and endemism

The identification of species of conservation concern and endemism was guided by Wilson and Mittermeier's (2009) "Handbook ot the Mammals of the World". This list is based on the work of Wilson and Reeder (Wilson, Reeder, 2005) and thus presents many differences in the status and rank of taxa (species vs sub species) when compared to the IUCN's listing. In general, in the Handbook of the Mammals of the World, a higher number of taxa, particularly rodents and ungulates, are elevated to the status of species. For example, the Serengeti White-bearded Wildebeest (*Connochaetes mearnsi*) is recognized as a species with limited distribution by Wilson and Mittermeier but is considered a sub-species of the Common Wildebeest (*Connochaetes taurinus*) by the IUCN. With regard to the global conservation status of species, where differences were recorded, the status listed by the IUCN was retained.

- **Margaret's Brush-furred Rat (*Lophuromys margarettae)* Not evaluated – 5 records, 5 individuals**

Five individuals were captured with rodent traps. All captures took place in the higher altitude regions of the study area, in the north at 2,400m and in the south at 2,600m. Such captures align with previous records which indicate that this species is confined to areas above 2,000m in Ugandan and Kenyan mountain ranges

- **African Savanna Elephant (*Loxodonta africana*) EN - 1 record, 1 individual**

Evidence of the presence of African Elephants was discovered by the FFMES team ornithologist in the Kinale Forest (eastern edge of Zone 5). While this evidence was recorded outside the study area (5 km east of the road), it is important to acknowledge this observation consdering the African Elephant's conservation status and its ability to move great distances, making it susceptible to crossing the road. The evidence was dung, which considering the speed of degradation of such evidence in a wet and humid rainforest system, highlights that the animal presence in the Kinale forest was less than 3 months old.

- **Fringe-eared Oryx (*Oryx callotis*) VU - 12 records, 95 individuals combined**

All data relating to this species was collected within the perimeter of the Marula Estates Conservation Area. Observations of some individuals with plastic sleeves on their horns perhaps indicates that these individuals were farm bred animals or part of a larger conservation project. Previous census data shows a maximum of 45 individuals in Marula Estates in 2014 and a minimum of eight in 2018. The species was not recorded on Soysambu Conservancy. Such recordings are in close proximity yet still outside of this species' distribution as listed by the IUCN, however it is important to consider that the IUCN's maps (https://www.iucnredlist.org/search) often have poor precision levels. In Kenya, the Fringe-eared Oryx is found in the south and south-east of the country in more arid habitats than those found in the study area (East, 1998). Such distribution thus further supports the notion that these individuals have been introduced and are not naturally occuring in the landscape. The global population of this species is estimated at 3000 / 4000 adult individuals (IUCN, 2021); however, records show a declining population as population estimates in the late 1990s numbered some 5240 individuals (East, 1998). Furthermore, in Kenya, the population of Oryx sp. (*Beisa* and *Callotis*) declined by 78.7% between 1977-1980 and 2011-2013 (Ogutu *et al*.,2016).

- **Giraffe (Masai and Nubian) (*Giraffa camelopardalis Ssp tipperlskirchi)* EN – (*Giraffa camelopardalis Ssp camelopardalis) CR* – 20 records, 47 individuals combined**

Two subspecies are present in the study area. *Ssp Tipperlskirchi* is considered to be naturally occuring and *ssp camelopardalis* is present as a result of translocation of wild populations into regional conservation areas or Nakuru National Park. The world population of the *ssp camelopardalis* subspecies is estimated at 2,098 individuals (808 in Kenya) including 1,468 adults, with an overall positive demographic trend. This subspecies has virtually disappeared from its natural range in Kenya (Fennessy *et al*., 2018). Records from previous surveys show the presence of 41 giraffes of the *Tipperlskirchi* subspecies in Marula Estates (May 2018) and 133 individuals without sub-species precision in Soysambu Conservancy (2019). Our observations indicate giraffe presence in the study area, specifically in the two conservation areas of Soysambu Conservancy and Marula Estates, on the eastern edge of Lake Naivasha and on the plateau south of the city of Naivasha. Individuals noted south of Naivasha and Marula Estates were of the *Tipperlskirchi* subspecies and those noted on Soysambu Conservancy were of the *camelopardalis* subspecies.

- **Leopard (*Panthera pardus*) VU – 9 records, 9 individuals combined**

Leopards were recorded on both the Soysambu Conservancy and Marula Estates conservation areas as well as the transitional escarpment zone between the Naivasha plateau and the southern afromontane area of the study area (zone 4). In this area of rugged terrain and natural woodland cover numerous signs of the presence of this species were identified. This area is also rich in small antelopes and Olive Baboons (*Papio Anubis*), key prey for leopards.

- **Common Hippopotamus (*Hippopotamus amphibious*) VU - 6 records, 31 individuals combined**

Hippopotamus were recorded in three separate areas during the field surveys: Lake Elmentaita, notably on the north shore in the Soysambu Conservancy, at three points in the Marula Estates Conservation Area and on the eastern edge of Lake Naivasha. The latter is most problematic with regard to the road expansion. There is evidence to indicate that the Hippopotamus residing in Lake Naivasha feed on the meadows bordering the road at night. In Marula Estates, there is evidence to indicate that some of the animals use rivers that appear to suffer from very low water levels in the dry season. This could hypothetically lead to the movement of individuals in search of water points and potentially lead to road crossings.

- **Plains Zebra (*Equus quagga*) NT - 142 records, 1580 individuals combined**

Plains' zebra were abundant in the conservation areas of Soysambu Conservancy and Marula Estates. Previous records report the presence of 1,801 individuals in Marula Estates (2018) and 4,179 individuals in Soysambu Conservancy (2019). This species is absent from the mountainous parts of the study area, but is present outside of any protective perimetres south of Naivasha. In this zone plains zebra were found right next to the road and in close proximity to urban areas. This presents a high risk of collision and indeed, the body of an individual, possibly a victim of a collision, was found during the April field survey in the lower part of zone 5, a location quite a distance from the majority of observations.

- **Cape Buffalo (*Syncerus caffer*) NT - 17 records, 93 individuals combined**

Most (16) records were from the Soysambu Conservancy and Marula Estates conservation areas. One additional record was within the Kenya Wildlife Services sanctuary where a single animal was encountered when retrieving the cameras deployed in that location. Apart from this single record, the species appear confined within the protected areas and not likely to represent a major issue for the road unless the fencing is compromised.

- **African Clawless Otter (*Aonyx capensis*) NT - 3 records, 3 individuals combined**

The signs of African Clawless Otters (footprints) were recorded at three separate points on small streams in the study area. Two were on mountain streams (zones 1 and 5) and one on an almost dry stream north of Elmentaita Lake in the Soysambu Conservancy.

- **Striped hyena (*Hyaena hyaena*) NT – 1 record, 2 individuals**

Camera trapping recorded two individuals in the northern part of the study area (zone 2), west of Nakuru. This sector is quite disturbed, has a strong human presence and is well developed for agriculture. The presence of the species was also recorded on the Marula Estates census in 2018 (1 individual).

Several species are not listed as species of concern but have a limited range, and were noted as present in the study area. These species are not listed by the IUCN, meaning they are considered as sub-species of a species with a larger distribution. They are listed below with the species they are recorded as by the IUCN:

- **Serengeti Thomson's Gazelle (*Eudorcas nasalis*) - IUCN name: Thomson's Gazelle (*Gazella thomsoni*) (98 records, 1,245 individuals combined).**

Common in the open plains of the Soysambu Conservancy and Marula Estates conservation areas. Well represented as free ranging animals in the grasslands of the plateau south of Naivasha. The species has a limited body size but does represent a sigificant risk if crossing the road.

- **Cavendish's Dik-dik (*Madoqua cavendishi*) - IUCN name: Kirk's Dik-dik (*Madoqua kirkii*) (52 records, 61 individuals combined).**

Present in areas of fairly dense thicket. This species appears much more abundant in the southern part of the study area, the eastern part of the Marula Estates conservation area, the hills on the eastern border of Lake Elmentaita and along the wooded escarpment south of Naivasha.

- **Kongoni (Coke's Hartebeest) (*Alcelaphus buselaphus ssp cokii*) - IUCN name: Hartebeest (*Alcelaphus buselaphus*) (6 records, 65 individuals combined).**

This species was noted in Marula Estates and free ranging on the plateau south of Naivasha. Census data from Soysambu Conservancy and Marula Estates conservation areas does not indicate the presence of this species at the former (2019) and mentions only seven individuals on the latter in 2018.

- **Serengeti Topi (*Damaliscus lunatus ssp jimela*) - IUCN name: Topi (*Damaliscus lunatus*) (4 records, 17 individuals combined)**

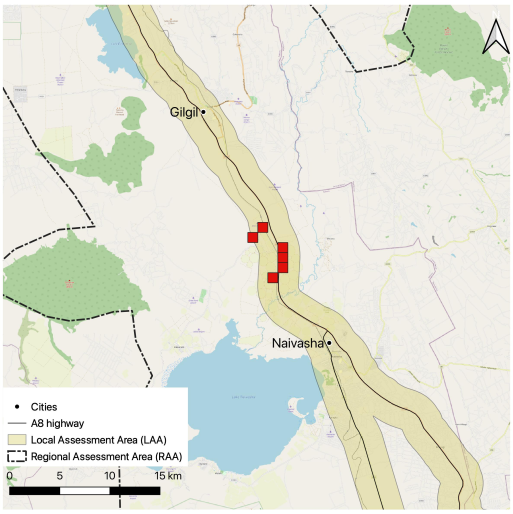
This species was noted only in the Marula Estates conservation area.

- **Serengeti White-bearded Wildebeest (*Connochaetes mearnsi*) - IUCN name: Common Wildebeest (*Connochaetes taurinus*) (9 records, 35 individuals combined).**

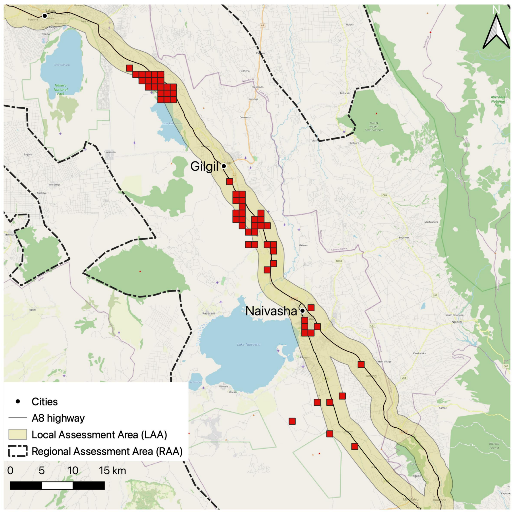
Noted in the Marula Estates conservation area but particularly south of Naivasha in close proximity to the lake and on the grasslands of the plateau, free ranging. Conservation area census data does not indicate the presence of the species on Soysambu Conservancy (2019) and mentions 84 individuals on Marula Estates in 2018. The species as susbtantial body size and represents a significant impact risk if it crosses the road.

- **Johnston's / Harvey's Duiker (*Cephalophus johnstoni / harveyi*) - IUCN name: Natal Red Duiker (*Cephalophus natalensis*) (1 record, 1 individual).**

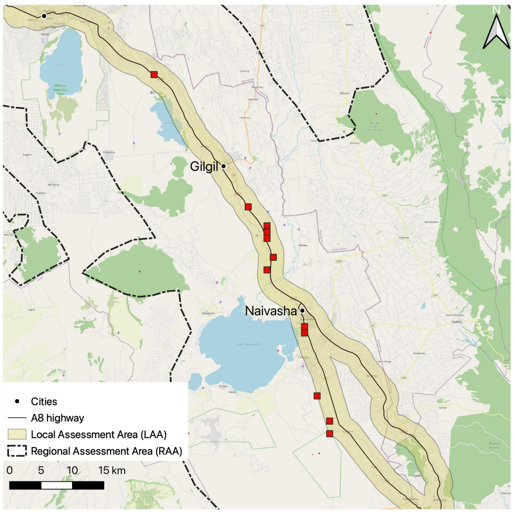
One record of this species was obtained via camera trapping during the April field survey in the mountain forest towards the eastern limit of the study area. Due to the quality of the image taken there is some uncertainty in the exact identification of the species, however, based on the body morphology it is most likely *harveyi*.



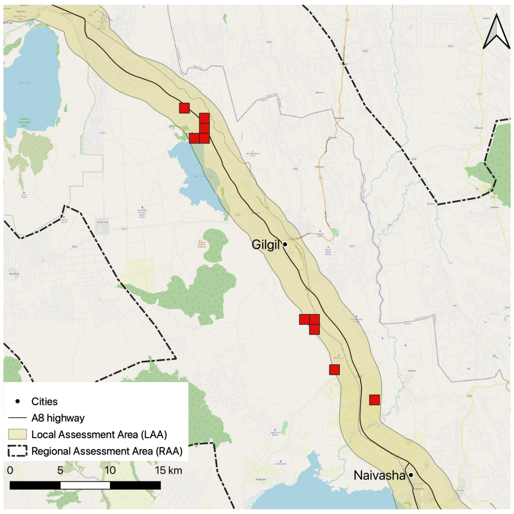
Fringe-eared Oryx (*Oryx callotis*)



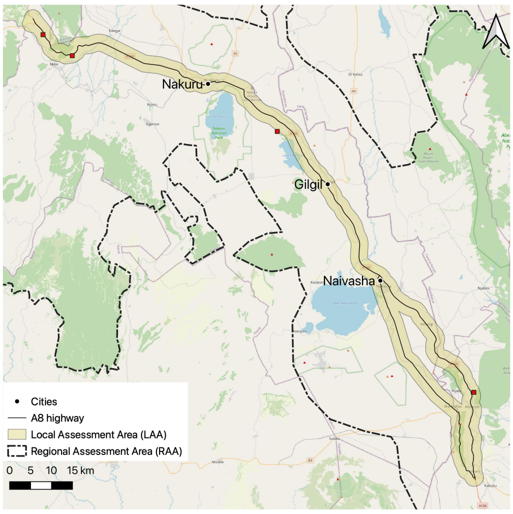
Plains Zebra (*Equus quagga*)



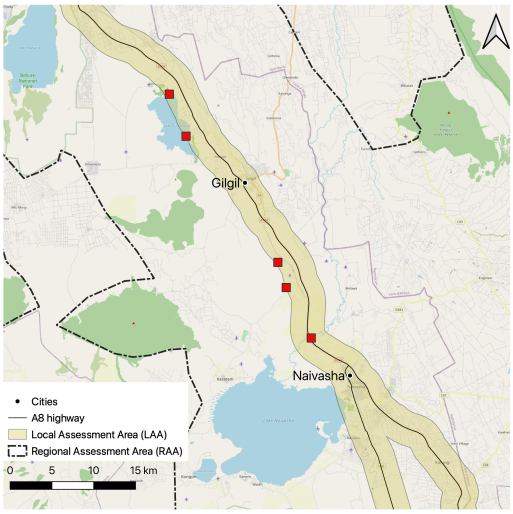
Giraffe (Rothschild) (*Giraffa camelopardalis*)



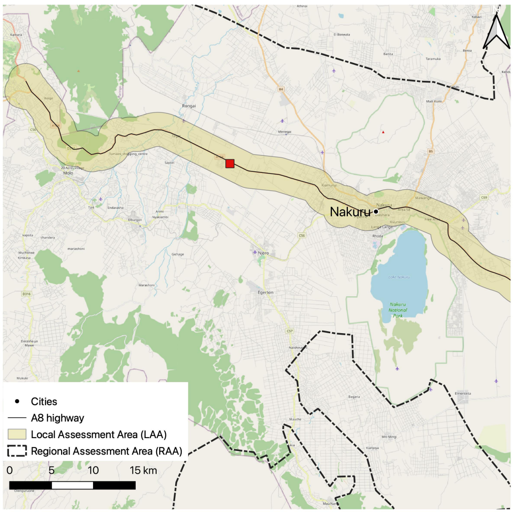
Cape Buffalo (*Syncerus caffer*)



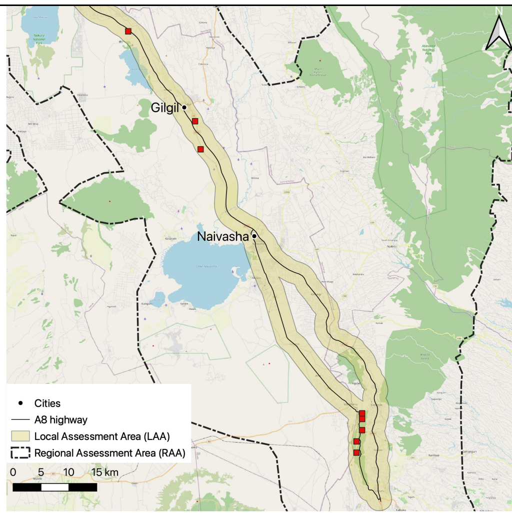
African Clawless Otter (*Aonyx capensis*)



Common Hippopotamus (*Hippopotamus amphibious*)

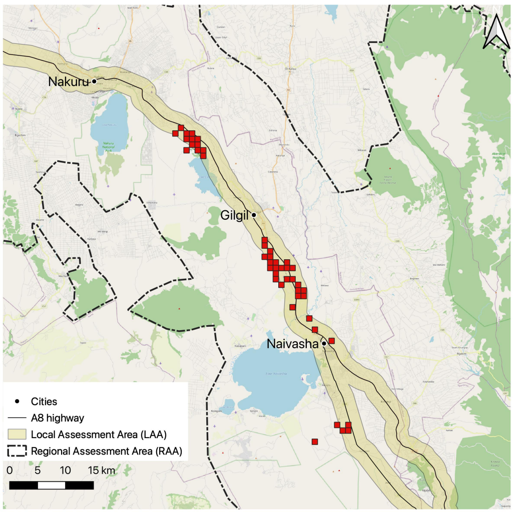


Striped hyena (*Hyaena hyaena*)

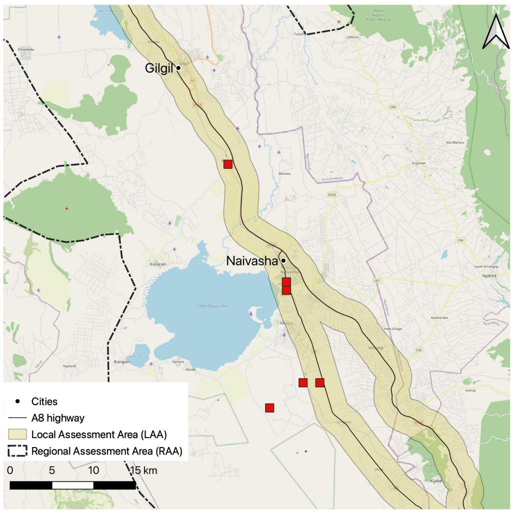


Leopard (*Panthera pardus*)

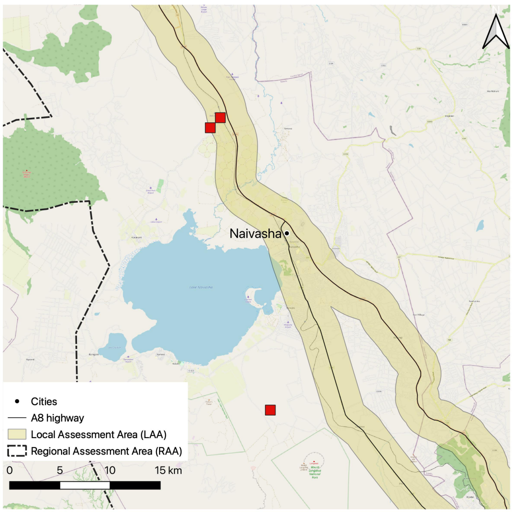
Figure 8: Distribution of data collected in the study area during the February and April 2021 field surveys for mammal species on the IUCN Red List of Threatened Species.



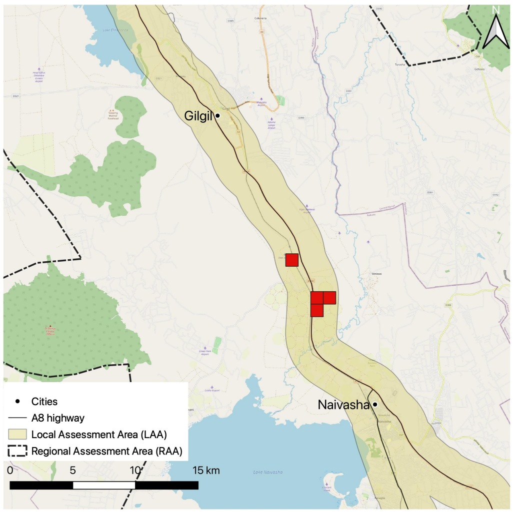
Serengeti Thomson's Gazelle (*Eudorcas nasalis*)



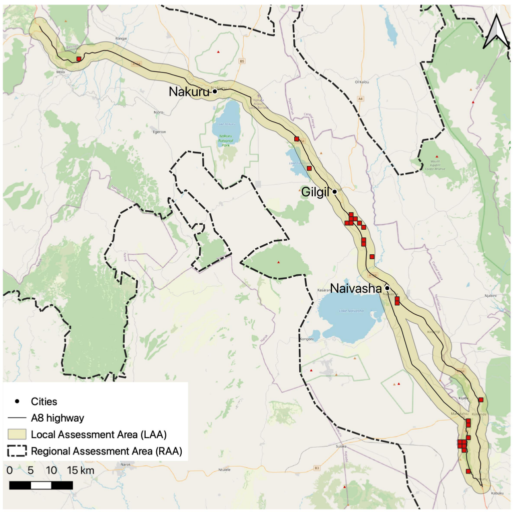
Serengeti White-bearded Wildebeest (*Connochaetes mearnsi*)



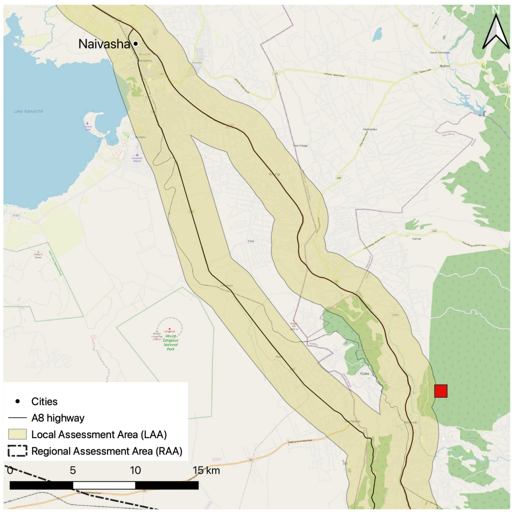
Kongoni (*Alcelaphus cokii*)



Seringeti Topi (*Damaliscus jimela*)



Cavendish's Dik-dik (*Madoqua cavendishi*)



Johnston's / Harvey's Duiker (*Cephalophus johnstoni / harveyi*)

Figure 9: Distribution of data collected in the study area during the February and April 2021 field surveys for species of mammals with reduced global distribution.

6.3 Synthesis

The presence of mammalian fauna of the study area is uneven. In general, the spaces characterised by human activities have a substantially lower mammal species richness. This is the case for the most urbanised areas but also for agricultural areas in the northern part of the study area (west of Nakuru) and some areas south of Naivasha.

Afromontane areas are generally neglected by medium-sized to large mammal species with the exception of rare recordings. This is the case for the majority of ungulates, whose absence is likely connected with the degradation of most habitats but could also be related to climatic factors and the nature of the original, undisturbed habitats.

The concentration of species and particularly ungulates can be observed in three areas: the two conservation areas of Soysambu Conservancy and Marula Estates as well as on the plateau south of Naivasha. These areas are also key habitat zones for many species listed on the IUCN World Red List of Threatened Species.

The southern afromontane area (zone 5 and border of zone 4) is of greater interest than that of the north (zone 1). The proximity of preserved environments such as the afromontane forests at its eastern edge and the persistence of a more substantial area of natural environments along the Naivasha plateau escarpment probably explains this. The northern area presents a dearth of preserved natural environments and is subject to greater human pressure.

The southern afromontane area still presents suitable habitat for small ungulates (e.g., dik-dik, duiker etc) and large carnivores (e.g., leopard, spotted hyena etc) and it remains pristine enough to be traversed by large herbivores of concern such as the Burchell zebra and elephant. This area therefore represents a key natural connectivity zone that needs to be considered for the placement of underpasses or overpasses.

Finally, functional groups of smaller species such as small antelopes and small carnivores have a wider and more homogeneous distribution on the study area. This is likely an indication of the adaptation of these species to human activities or of their ability to co-exist within the genally agricultural habitat matrix developed by humans.

Further considerations should also be placed on the role of the southern part of the study area (zones 4 and 5) acting as an axis of movement for large mammals migrating between the Aberdare Mountains and the protected areas in the west.

Figure 10: Distribution of data collected in the study area during the February and April 2021 field surveys of some functional groups of mammals.

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

The study area is located in an area known for its high ecological value and biodiversity. It is integrated by Ogutu as part of Kenya Vision 2030 Flagship Project "Securing Wildlife Migratory Routes and Corridors" in the "Southern Kenya Rangeland Ecosystem" under the denomination "Naivasha-Nakuru Eburu area" (Ogutu, 2016). This area is identified as being among the most in need of conservation policy focus, notably there is a need for the maintenance of corridors between natural areas regardless of their protection status. Ecologically, this region suffers due to agricultural development, industrial infrastructure and human population growth (Ojwang *et al.*, 2017).

As such, the roads that comprise the focus of this study already represent ecologically harmful infrastructure particularly in relation to the movement of animal populations. It generates multiple impacts through different forms of pollution and the risk of collisions.

During the field surveys we identified a number of negative points for the conservation of mammals and highlighted the importance of maintaining opportunities for animals to cross the road safely. These negative points are both directly and indirectly reated to the road expansion. In order to reduce the impacts of this project there is a requirement for compensatory action, including mitigating effects which may not be directly caused by the project. These impacts are likely to have an equivalent impact on mammals.

7.1 Traffic disruption

This road is already both a direct and indirect barrier in three ways:

- The traffic on this road is of considerable density and often represents a veritable wall of vehicles making crossing perilous, which constites a strong repulsive effect for wildlife, even for those that may have become habituated;[1]
- on certain sections where doubling of the lanes is already in place, the pavement separating flows of traffic blocks mammals from crossing the road (zones 1 and 2);
- The Soysambu Conservancy and Marula Estates conservation areas are housed by fences (both electrified and not) and thus no movement between these areas is possible.

At the project level scale, there are a number of key issues that will directly impact mammal conservation. Long term viability of species populations is extremely important and thus the conservation of mammals requires conservation of all life stages and maintenance of genetic material and exchange opportunities.

7.2 Cumulative effect of improvements

In the southern part (zone 4) we also saw the works relating to the construction of the Nairobi-Naivasha Gauge Railway. The shape of this embankment railway is a barrier for larger fauna. The development for the new railway may combine with the road development and further limit the movement of mammals on a broader scale but equally at a local level involving movement of species on the plateau between Lake Naivasha and Longonot Volcano National Park.

7.3 Road mortality by collision

No collision mortality assessment was carried out during the field surveys. However, chance observations of the carcasses of an olive baboon in zone 4 and a possible plains' zebra in zone 5 were observed along the main highway. The risk of collision is therefore real, especially on the A8 south Highway.

[1] This aspect can be viewed in a positive way in the sense that it may contribute to the reduction in road collisions. However, its effect differs between species.

7.4 No wildlife crossings

There is currently a lack of dedicated wildlife crossing points along the road. Only a few bridges, underpasses and streams can be used for secure crossings. Most of these structures do not cater to the needs of large species, particularly giraffe.

7.5 Division of space

In general, the landscape of the study area and the territory encompassed is heavily partitioned (roads and infrastructures, fences, thorny hedges installed, power lines…). This partitioning also exists in conservation areas, especially in Marula Estates, where to the east of the road, a group of fences enclose different sectors, probably as “paddocks” for cattle, even though they contain the same type of vegetation. To the west of the road, a fence remains along the old road which which runs parrallel with the current A8 Highway.

7.6 Land development

The landscape of the study area takes on a mosaic structure. In many parts (especially the southern half of the study area) large natural environments are interwoven with agricultural land, dwellings, greenhouses and industrial-type buildings, without much attention to coherence or urban planning. The result is a strengthening of the fragmentation and separation of natural environments, representing a loss of ecological potential as larger and complete units of natural habitats are often the most valuable for ecological resilience. Furthermore, the establishment of buildings and human activities increases human pressure on landscapes by disturbance (albeit involuntary) in comparison to a landscape comprised of natural habitats. Finally, the dispersal of human related businesses, homes and production sites requires an increase in energy provisionning infrastructure development and, by association the establishment of access infrastructure and related increase in traffic required for such energy provision.

Table2: Proposal of Compensatory Measures

Type of impact	Reduction or compensation measure for negative effects
Traffic disruption	- Creating a dense network of wildlife crossings to maintain or improve the ability of mammals to cross the road. In addition to dedicated under-ground or air crossings, all infrastructure must be resized and used for the movement of animals (bridges and crossing of tracks and roads, bridges spanning waterways...) - Beyond this, a "corridor" program must be established to enable in a durable manner the movement of mammals in the area. The Nakuru NP / Naivasha Lake / Longonot NP axis on the one hand and the Kinale Forest / Hell's Gate NP axis on the other hand appear as clear priorities. - Actions must include the erasure of fences and 20kv overhead powelines (known to affect giraffe in the study area) and focus on the creation of long-lasting wildlife friendy crossings etc. as well as maintaining a sufficient number of patches of natural habitat of suitable size with good interconnexion. - Give space to wildlife within the two conservation areas of Soysambu Conservancy and Marula Estates. In Marula Estates, the territory including natural environments that are frequented by large fauna is fragmented by numerous fences. It may be judicious to engage with the land owner to investigate the reduction of the number of such barriers, or at least investigate how to increase the permeability of such barriers to wildlife movement[2]. This work must include consideration for the location, number and type of wildlife crossings to ensure complementarity.
Cumulative effect of improvements	- Where available, identify any compensatory measures implemented by the railway project and integrate them to generate complementarity with the measures identified on the road project. Ensure that the combined infrastructure projects do not place emphasis on different locations for crossings and different species.
Road mortality by collision	- Create a dense network of wildlife crossings to maintain or improve the opportunity for mammal crossing. In addition to dedicated under-ground or aerial crossings, the entire infrastructure must be resized and put to use for the movement of animals (bridges and crossings of tracks and roads, bridges spanning waterways...).
No wildlife crossings	- Create a dense network of wildlife crossings to maintain or improve the ability of mammals to cross the road. In addition to dedicated under-ground or air crossings, all infrastructure must be resized and used for the movement of animals (bridges and crossings of tracks and roads, bridges spanning waterways...)

[2] Depending on body size there are many wildlife species that can be accomodated through fences using specially developed “passages” that will block cattle but let wild animals through.

Division of space	- Completion of a related study on the best methods of implementation of corridors on the axes Nakuru NP / Lake Naivasha / Longonot NP and Forest Kinale / Hell's Gate NP
Land development	- Incorporate the"Wildlife Migratory Corridors and Dispersal Areas" objective into land use policy and urban planning. With particular focus on land management, there is a need for long-term conservation of vast and connected natural environments. At the same time urban "corridors" linking areas with low or no industrial or residential construction dedicated to the circulation of wildlife should be maintained. Ideally corridors should be occupied by natural vegetation or unfenced grasslands.

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9 APPENDIX I LIST OF MAMMAL SPECIES (FEBRUARY AND APRIL 2021)

Primates
Cercopithecidae
Papio anubis Olive Baboon LC
Chlorocebus pygerythrus Vervet Monkey LC
Colobus guereza Guereza LC
Cercopithecus albogularis Syke's Monkey LC

Lagomorpha
Leporidae
Lepus capensis Cape Hare LC
Lepus victoriae African Savanna Hare LC

Rodentia
Sciuridae
Xerus rutilus Unstriped Ground Squirrel LC
Heliosciurus rufobrachium Red-legged Sun Squirrel LC
Spalacidae
Tachyoryctes splendens African Root Rat LC
Hystricidae
Hystrix cristata / africaeaustralis Crested / Cape Porcupine LC
Gliridae
Graphiurus kelleni Kellen's African Dormouse LC
Nesomydae
Dendromus insignis Montane African Climbing Mouse LC
Dendromus messorius Banana African Climbing Mouse LC
Cricetomys ansorgei Southern Giant Pouched Rat LC
Muridae
Otomys angoniensis Angoni Vlei Rat LC
Arvicanthis niloticus / nairobae African Grass Rat – Nairobi Grass Rat LC
Grammomys ibeanus / dolichurus East African / Woodland Thicket RatLC
Lemniscomys striatus Typical Striped Grass Mouse LC
Oenomys hypoxanthus Common Rufous-nosed Rat LC
Rhabdomys dilectus Mesic Four-striped Grass Rat NR
Mus minutoides Sub-Saharan Pygmy Mouse LC
Mus triton Gray-bellied Mouse LC
Mastomys natalensis Natal Multimammate Mouse LC
Rattus rattus Roof Rat LC
Lophuromys margarettae Margaret's Brush-furred Rat NR

Carnivora
Felidae
***Panthera pardus* Leopard VU**
Leptailurus serval Serval LC
Viveridae
Civettictis civetta African Civet LC
Genetta maculata Large Spotted Genet LC
Hyaenidae
Crocuta crocuta Spotted Hyena LC
***Hyaena hyaena* Striped hyena NT**

Herpestidae
Herpestes ichneumon Egyptian Mongoose LC
Galerella sanguinea Common Slender mongoose LC
Ichneumia albicauda White tailed mongoose LC
Canidae
Canis mesomelas Black-backed Jackal LC
Otocyon megalotis Bat-eared Fox LC
Mustelidae
Mellivora capensis Honey badger LC
Ictonyx striatus Zorilla LC
***Aonyx capensis* African Clawless Otter NT**

Hoofed Mammals
Orycteropodidae
Orycterop afer Aardvark LC
Procaviidae
Procavia capensis Rock Hyrax LC
Elephantidae
***Loxodonta africana* African Savanna Elephant VU**
Equidae
***Equus quagga* Plains Zebra NT**
Suidae
Phacochoerus africanus Common Warthog LC
Potamochoerus larvatus Bushpig LC
Hippopotamidae
***Hippopotamus amphibius* Common Hippopotamus VU**
Bovidae
***Syncerus caffer* Cape Buffalo NT**
Tragelaphus sylvaticus Cape Bushbuck LC
Taurotragus oryx Common Eland LC
Aepyceros melampus Common Impala LC
Raphicerus campestris Capricorn LC
Nanger granti Grant's Gazelle LC
Eudorcas nasalis Serengeti Thomson's Gazelle LC
Madoqua cavendishi Cavendish's Dik-dik LC
Redunca redunca Bohor Reedbuck LC
Kobus defassa Defassa Waterbuck LC
***Oryx callotis* Fringe-eared Oryx EN**
Alcelaphus cokii Kongoni LC
Damaliscus jimela Seringeti Mice LC
Connochaetes mearnsi Serengeti White-bearded Wildebeest LC
Sylvicapra grimmia Common Duiker LC
Cephalophus johnstoni / harveyi Johnston's / Harvey's Duiker LC
***Giraffa camelopardalis* Giraffe (Masai / Rothschild) VU**

10 APPENDIX II MAMMAL SPECIES ENCOUNTERS – SUMMARY TABLE (FEBRUARY AND APRIL 2021)

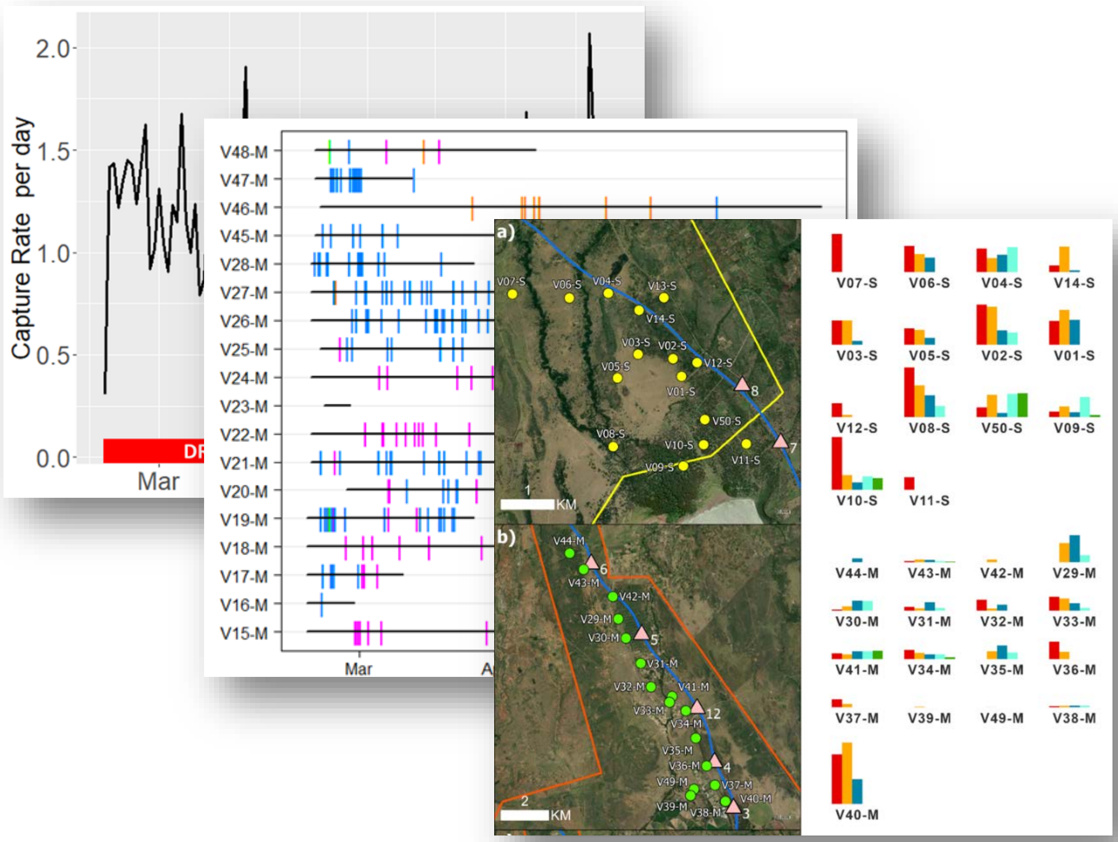
Family	Species	Common Name	Secondary Data Field Campaign		Collection method					Habitat where surveyed													Special status		
			February	April	Active search for presence indicies and direct observations	Direct observations by road	Short-term camera trapping	Small mammal trapping	Additional data	Upper acacia wooded grassland	Riverine wooded vegetation	Montane ericaceous belt	Halohytic vegetation	Freshwater swamp	Evergreen and semi-evergreen bushland and thicket	Edaphic wooded grassland	Dry transitional forest	Afromontane un-differentiated forest	Afromontane rainforest	Afromontane desert	Afromontane bamboo	Afroalpine vegetation	IUCN Red List	Protected in Kenya (Kenya Wildlife Service, 2021)	Endemic
Orycteropodidae	*Orycterop afer*	Aardvark	x	x	x		x			x					x			x					LC		
Viverridae	*Civettictis civetta*	African civet	x	x			x								x			x					LC		
Mustelidae	*Aonyx capensis*	African clawless otter	x	x	x				x						x	x		x					LC		
Muridae	*Arvicanthis niloticus / nairobae*	African grass rat - Nairobi grass rat	x					x							x								LC		
Spalacidae	*Tachyoryctes splendens*	African root rat	x	x				x		x					x	x		x			x		LC		
Elephantide	*Loxodonta africana*	African savanna elephant		x					x										x				EN	x	
Leporidae	*Lepus victoriae*	African savanna hare		x			x			x								x					LC		
Muridae	*Otomys angoniensis*	Angoni vlei rat	x	x				x			x							x					LC		
Nesomyidae	*Dendromus messorius*	Banana african climbing mouse		x				x										x					LC		
Canidae	*Otocyon megalotis*	Bat eared fox	x	x	x		x				x				x								LC		
Canidae	*Canis mesomelas*	Black backed jackal	x	x	x		x						x		x								LC		
Bovidae	*Redunca bohor*	Bohor reedbuck	x				x				x												LC		
Bovidae	*Sylvicapra grimmia*	Common/bush duiker	x	x	x		x			x	x				x			x			x		LC		
Suidae	*Potamochoerus larvatus*	Bushpig		x			x				x												LC		
Bovidae	*Syncerus caffer*	Cape buffalo	x	x	x		x						x		x								NT		
Bovidae	*Tragelaphus sylvaticus*	Cape busbuck	x	x			x				x										x		LC		
Leporidae	*Lepus capensis*	Cape hare	x	x	x		x								x			x					LC		
Bovidae	*Madoqua cavendishi*	Cavendish's dik dik	x	x	x		x				x				x			x					LC		
Bovidae	*Taurotragus oryx*	Common eland	x	x	x		x				x				x								LC		
Hippopotamidae	*Hippopotamus amphibius*	Common hippopotamus	x	x	x		x				x				x								VU		
Bovidae	*Aepyceros melampus*	Common impala	x	x	x		x				x		x		x								LC		
Muridae	*Oenomys hypoxanthus*	Common rufous-nosed rat		x				x										x					LC		
Herpestidae	*Galerella sanguinea*	Common slender mongoose		x			x			x													LC		
Suidae	*Phacochoerus africanus*	Common warthog	x	x	x		x				x		x		x			x					LC		
Hystricidae	*Hystrix cristata*	Crested porcupine	x	x			x			x	x				x			x					LC		
Bovidae	*Kobus defassa*	Defassa waterbuck	x	x	x		x				x		x		x								LC		
Muridae	*Grammomys ibeanus / dolichurus*	East African / woodland thicket rat		x				x			x												LC		
Herpestidae	*Herpestes ichneumon*	Egyptian mongoose	x	x		x	x		x	x	x				x			x					LC		
Bovidae	*Oryx callotis*	Fringe-eared oryx	x	x	x		x				x				x								VU		
Giraffidae	*Giraffa camelopardalis Ssp Tipperlskirchi / Camelopardalis*	Giraffe (Maisai & Nubian)	x	x	x		x				x				x								VU	x	
Bovidae	*Nanger granti*	Grant's gazelle	x	x	x		x								x								LC		
Muridae	*Mus triton*	Gray-bellied mouse		x				x							x			x					LC		
Cercopithecidae	*Colobe guéréza*	Guereza	x	x	x								x		x			x	x		x		LC		
Mustelidae	*Mellivora capensis*	Honey badger		x			x			x					x								LC		
Bovidae	*Cephalophus johnstoni / harveyi*	Johnston's / Harvey's duiker		x			x														x		LC		
Gliridae	*Graphiurus kelleni*	Kellen's African dormouse	x					x							x								LC		

Family	Species	Common Name	Secondary Data Field Campaign		Collection method					Habitat where surveyed													Special status		
			February	April	Active search for presence indicies and direct observations	Direct observations by road	Short-term camera trapping	Small mammal trapping	Additional data	Upper acacia wooded grassland	Riverine wooded vegetation	Montane ericaceous belt	Halohytic vegetation	Freshwater swamp	Evergreen and semi-evergreen bushland and thicket	Edaphic wooded grassland	Dry transitional forest	Afromontane un-differentiated forest	Afromontane rainforest	Afromontane desert	Afromontane bamboo	Afroalpine vegetation	IUCN Red List	Protected in Kenya (Kenya Wildlife Service, 2021)	Endemic
Bovidae	*Alcelaphus cokii*	Kongoni	x	x	x		x								x								LC		
Viverridae	*Genetta maculata*	Large spotted genet		x			x								x						x		LC		
Felidae	*Panthera pardus*	Leopard	x	x	x		x								x			x					VU	x	
Muridae	*Lophuromys margarettae*	Margaret's brush-furred rat	x	x				x										x					Not recorded on IUCN red list		
Muridae	*Rhabdomys dilectus*	Mesic four-striped grass rat		x				x										x					Not recorded on IUCN red list		
Nesomyidae	*Dendromus insignis*	Montane African climbing mouse		x				x										x					LC		
Muridae	*Mastomys natalensis*	Natal multimammate mouse	x	x				x										x					LC		
Cercopithecidae	*Papio anubis*	Olive baboon	x	x	x	x					x		x		x			x					LC		
Equidae	*Equus quagga*	Plains zebra	x	x	x		x				x		x		x			x					NT		
Sciuridae	*Heliosciurus rufobrachium*	Red-legged sun squirrel	x	x	x										x			x					LC		
Procaviidae	*Procavia capensis*	Rock hyrax	x	x	x		x								x			x					LC		
Muridae	*Rattus rattus*	Roof rat		x				x		x					x			x					LC		
Bovidae	*Eudorcas nasalis*	Serengeti Thomson's gazelle	x	x	x		x				x		x		x								LC		
Bovidae	*Connochaetes mearnsi*	Serengeti white-bearded wildebeest	x	x	x		x				x				x								LC		
Bovidae	*Damaliscus jimela*	Serengeti topi	x	x	x		x				x				x								LC		
Felidae	*Leptailurus serval*	Serval		x			x			x													LC		
Bathyergidae	*Heliophobius argenteocinereus*	Silvery mole-rat		x				x							x								LC		
Nesomyidae	*Cricetomys ansorgei*	Southern giant pouched rat		x				x													x		LC		
Hyaenidae	*Crocuta crocuta*	Spotted hyena	x	x	x		x								x			x					LC		
Bovidae	*Raphicerus campestris*	Steenbok		x			x			x					x								LC		
Hyaenidae	*Hyaena hyaena*	Striped hyena		x			x			x													NT	x	
Muridae	*Mus minutoides*	Sub-Saharan pygmy mouse	x	x				x			x				x			x					LC		
Cercopithecidae	*Cercopithecus albogularis*	Syke's monkey	x	x	x		x				x				x			x	x		x		LC		
Muridae	*Lemniscomys striatus*	Typical striped grass mouse	x	x				x		x	x				x			x					LC		
Sciuridae	*Xerus rutilus*	Unstriped ground squirrel	x		x										x								LC		
Cercopithecidae	*Chlorocebus pygerythrus*	Vervet monkey	x	x	x		x			x	x				x								LC		
Herpestidae	*Ichneumia albicauda*	White-tailed mongoose	x	x			x				x				x			x			x		LC		
Mustelidae	*Ictonyx striatus*	Zorilla	x	x			x				x				x			x					LC		
Totals			**45**	**60**	**30**	**2**	**41**	**17**	**3**	**14**	**28**	**0**	**9**	**0**	**46**	**2**	**0**	**32**	**3**	**0**	**9**	**0**		**4**	

APPENDIX

6-19 *CAMERA TRAP STUDY*

Nairobi-Nakuru-Mau Summit highway wildlife connectivity assessment: camera trap study



Dr Alex M. Lechner, Michelle Ang and Darrel Tiang

31 July 2021

Nairobi-Nakuru-Mau Summit highway wildlife connectivity assessment: camera trap study

Report by Dr Alex M. Lechner, Michelle Ang and Darrel Tiang

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Contents

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Glossary

Below is a list of commonly used modelling terms in the report. The terms have been defined from the perspective of this report which in some cases may differ slightly from there general usage.

Term	Definition
Camera deployment period	The period from when the camera was installed to its last known day of operation. Cameras ceased to operate due to being stolen, damaged by wildlife, flat battery or malfunctioned for other reasons.
Active camera	A 24-hour period in which the camera was confirmed operational based on successful image transmission.
Camera detections/capture	Photos with wildlife with one or more individuals detected in a single image– recorded as a single detection.
Capture rate	The number of total individuals recorded per day or per 100 days.
Sites	The data were grouped and analysed for three sites: Soysambu, Marula East and Marula West.
Time interval	Time-interval between camera detections used to address pseudo-replication; where the same individual appears in different images, but is treated as independent detections. We used a 30 minute interval for the study.
Total Individual detections	Count of the total number of individuals for each species within a single image. This term contrasts with 'camera detections' which describes only the presence or absence of a specific species in an image.
Wet and dry months	Dry month was February and the wet months were March to May.
WLC	Wildlife crossing.

Executive summary

The University of Nottingham Malaysia was commissioned by WSP Canada on behalf of Rift Valley Highways Limited Consortium (RVHL), Government PPP Partners to assess the potential impacts of the proposed upgrade of the Nairobi-Nakuru-Mau Summit highway on ecological connectivity and inform the identification of the optimal locations for the wildlife crossing structures.

This study focused on the analysis of camera trap data collected by WSP Canada as part of the Environmental and Social Impact Assessment (ESIA) to identify locations with high species abundance and diversity of selected conservation target species to support the identification of optimal locations of wildlife crossing structures. All wildlife detected on the cameras were identified to species by WSP, but this analysis focuses on four key conservation target species: African buffalo (*Syncerus caffer*); Giraffe (*Giraffa spp.*); Plains zebra (*Equus quagga*); and Spotted hyena (*Crocuta crocuta*). Data from other species and justification for the choice of species is presented elsewhere in the ESIA.

The aim of this project is to characterise data from 50 cameras deployed for varying lengths of time between 17th of February and 10th of June 2021 in order to assess the following:

- Camera operational activity times
- Capture rates (number of detections per camera divided by the number of days the camera was functional) for individual species and all species
- Characterisation of differences in capture rates based on wet and dry months
- Spatial distribution of captures

The analysis was carried out using data from 50 cameras deployed at three sites, namely Soysambu and Marula Estate (east and west of the highway) conservancies. Cameras were only deployed at these locations because of the high quality and extent of habitat and wildlife in these areas and due to the lower risk of damage or theft to cameras. Wildlife crossing structures are proposed for these two areas as well as locations further north and south.

The total sampling period was 113 days, with a combined total of 3415 active camera trap days. In Soysambu, Marula West and Marula East, there were 15, 17 and 18 cameras deployed respectively. The maximum number of cameras active at any time was 48 from February 26th to 27th and decreased after this time, with the 10th of June representing the last date when a camera recorded a capture and only 13 cameras remained active. Over the course of the camera survey the number of deployed cameras, active cameras, detection and number of individuals detected decreased over time.

The total number of wildlife detections (i.e. one or more individuals of Zebra, Giraffe, Buffalo or Hyena identified in a single photo) taken at 30 minute independent intervals was 1,917 and a total of 3,283 individuals were detected. Zebra were the most numerous species detected (n = 2,953) followed by Buffalo (n = 153), Giraffe (n = 100) and Hyena (n = 77). Zebra were detected at almost all cameras, (n = 46) and Giraffe were detected at the least (n = 12). A site-level covariance analysis showed that Hyena, Zebra and Buffalo are mostly present at the same locations as indicated by positive covariances. In contrast, Giraffe were mostly present in areas where other species were less abundant as described by their negative covariance with other species.

Overall, it appears that there were more frequent detections of the four target species in Soysambu and Marula West. Of the four target species, Zebra were detected most frequently and was found across all locations, but with the majority of detections in Marula East and West. For the Buffalo, there were more detections in Marula West and Soysambu, though many cameras failed to detect the species. In contrast, Giraffe were mainly found in Marula East, with no detections in Soysambu and almost no detections in Marula West. Finally, for Hyena, this species was detected in all three sites though in low numbers.

Comparing between the survey months, the dry month of February had a higher capture rate compared to the wet months of March to May. Overall, there was a dip in the overall capture rate during the wet months from March to May. However, the patterns of capture rates per species over time seemed relatively consistent, especially for camera locations with high capture rates. As would be expected, cameras with lower samples tended to fluctuate more between time periods.

The camera trap data provide a good indication of the species found and their relative abundance at specific locations in the regional assessment area (RAA). These data provide useful support for guiding the assessment and selection of wildlife crossing areas for mitigating the impact of the road on connectivity. The data need to be considered within the context of other datasets and on the ground expert advice.

1.0 Introduction

1.1. Background

The University of Nottingham Malaysia was commissioned by WSP Canada on behalf of Rift Valley Highways Limited Consortium (RVHL), Government PPP Partners to assess the potential impacts of the proposed upgrade of the Nairobi-Nakuru-Mau Summit highway on ecological connectivity and inform the identification of the optimal locations for the wildlife crossing structures.

This study focused on the analysis of camera trap data collected by WSP Canada as part of the ESIA to identify locations with high species abundance and diversity to support the identification of optimal locations of wildlife crossing structures. All wildlife detected on the cameras were identified to species by WSP but this analysis focuses on four key conservation target species: African buffalo (*Syncerus caffer*); Giraffe (*Giraffa spp*); Plains zebra (*Equus quagga*); and Spotted hyena (*Crocuta crocuta*). The choice of the four key conservation targets and data from other species is presented elsewhere in the ESIA.

The analysis was carried out in three sites which represent a subset of the total locations covered by the Environmental and Social Impact Assessment (ESIA) and does not include all wildlife crossings:

- Soysambu
- Marula West
- Marula East

1.2. Scope and aims

The aim of this project is to characterise the camera trap data gathered from 50 cameras deployed at different intervals between 17th of February to 10th of June 2021 in order to assess the following:

- Capture rates for individual species and all species
- Characterisation of differences in capture rates based on wet and dry months
- Spatial distribution of capture rates for the three sites

2.0 Methods

2.1. Methods overview

This study analysed camera trap data to identify camera locations with high species abundance and diversity to support the identification of wildlife crossing locations.

Eight steps in this study are as follows:

- Characterise camera deployment period and activity
- Summarise overall patterns of individuals captured
- Assess site-level species covariance
- Document daily patterns in wildlife detection
- Summarise the capture rate and spatial distribution of wildlife over time, including during the wet and dry month

2.2. Conservation targets and study area

The Environmental and Social Impact Assessment (ESIA) for the Rironi to Mau Summit Highway Expansion and Upgrade project was conducted by WSP Canada and commissioned by Rift Valley Highway Limited (RVHL). As part of the ESIA, the Flora and Fauna & Man, Ecological Services Ltd (FFMES) was commissioned by WSP Canada to undertake the camera deployment along the proposed road alignment as part of the biodiversity baseline investigation on mammals.

The survey was conducted within the vicinity of Soysambu and Marula Estates conservation areas from the 17th February to the 10th June 2021. Many species were detected during this survey and the full results are presented elsewhere in the ESIA. This report focussed on the following four key species which were recorded from the camera trap images:

- African buffalo (*Syncerus caffer*) referred to as Buffalo
- Giraffe (*Giraffa spp.*). It is important to note that Soysambu Wildlife Conservancy has Nubian giraffe only (*Giraffa c. camelopardalis*), whereas Marula Estate has Masai giraffe (*Giraffa tippelskirchi*). However, the analysis conducted for this study uses the term Giraffe to refer to both species.
- Plains zebra (*Equus quagga*) referred to as Zebra
- Spotted hyena (*Crocuta crocuta*) referred to as Hyena

2.3. Long-term camera trap survey

2.3.1. Camera locations

Fifty camera traps with LTE connectivity (VOSKER V200 LTE Wireless Outdoor Security Camera) were deployed along the highway (Figure 1) from the 17th February 2021 for up to five months. Unfortunately, throughout the deployment period, there were multiple technical issues that occurred which may have affected camera capture. This included periods of inactivity between deployment, issues associated with battery life, cameras being accidently moved or damaged by wildlife or cameras vandalised or stolen, such as the two cameras, V13-S and V23-M which were no longer active less than a week after deployment (Mottram et al., 2021). Hence, while a total of 50 cameras were deployed initially, only 48 were operational at any given date due to the different deployment duration and periods of inactivity. This will be further explained and illustrated in the results section 3.1.

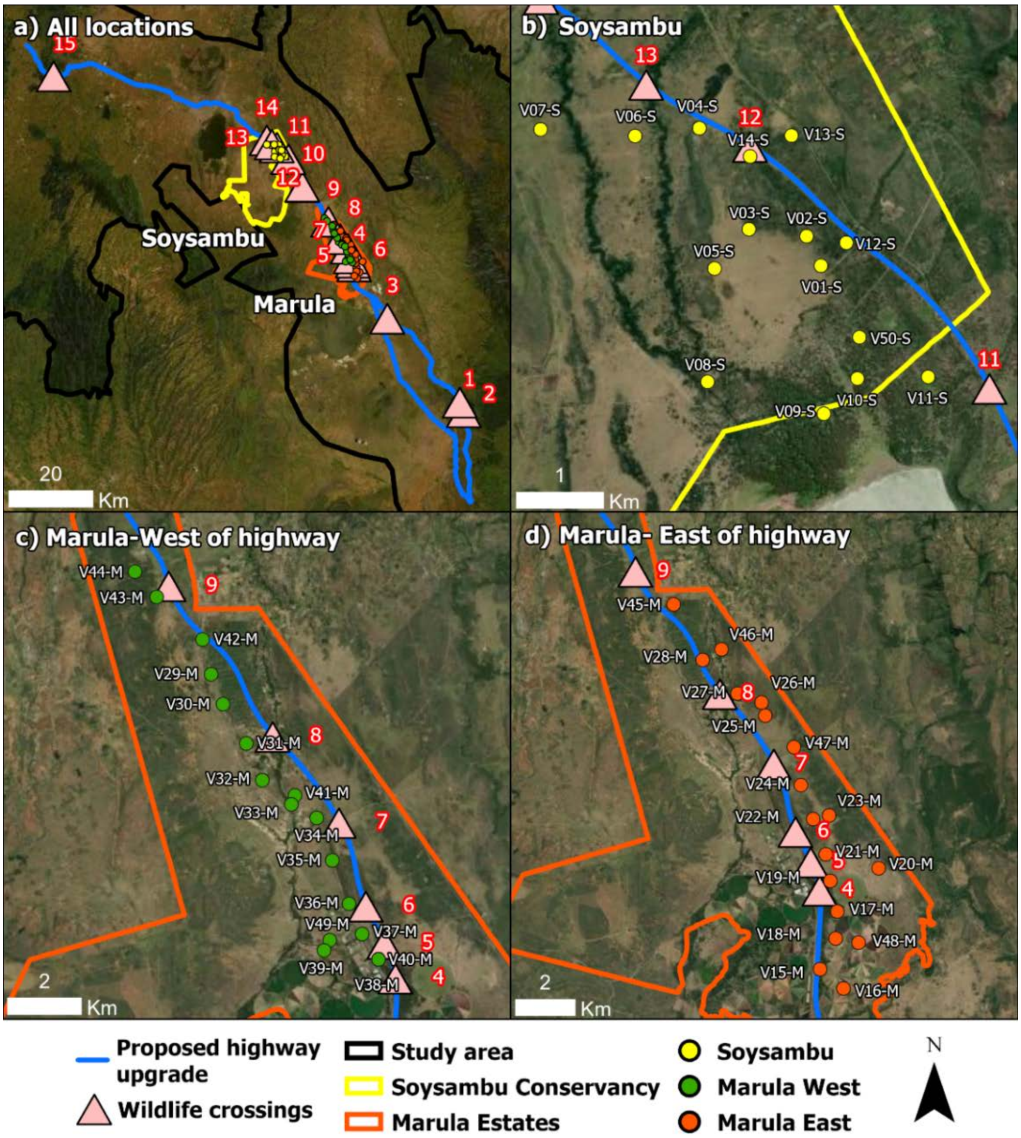

Figure 1: The locations of 50 cameras which were deployed from 17th February to the 10th June 2021. The locations of wildlife crossings are also included.

A total of 9 out of the 15 proposed wildlife corridors were located in close proximity to the camera trap locations in the Marula and Soysambu estates (Figure 1 and Table 1).

Table 1: Proposed wildlife crossing locations (KWS 2019) and proximity to the camera traps in Soysambu or Marula.

FID	Road Section	Construction	Chainage (km)	Size (m)	Location	Description	Nearest Camera trap location
WLC1	1	Underpass	22+825	1 x 5 (W) x 3.5 (H)	Kijabe	Maintain Existing Underpass	N/A
WLC2	1	Underpass	25+325	1 x 5 (W) x 3.5 (H)	Kijabe	Demolition & reconstruction	N/A
WLC3	1	Underpass	53+375	2 x 7 (W) x 3.5 (H)	Naivasha East	New Multipurpose Underpass for KWSTI	N/A
WLC4	2	Underpass	69+235	1 x 5 (W) x 3.5 (H)	Marula	Demolition and reconstruction Underpass for Wildlife and livestock	Marula
WLC5	2	Overpass	70+220	1 x 30 (W)	Marula	New Overpass, 30 m width	Marula
WLC6	2	Underpass	71+340	1 x 5 (W) x 3.5 (H)	Marula	New Underpass	Marula
WLC7	2	Underpass	73+705	3 x 5 (W) x 3.5 (H)	Kigio	Demolition & reconstruction Underpass	Marula
WLC8	2	Underpass	76+640	1 x 7 (W) x 3.5 (H)	Gilgil River	New Underpass	Marula
WLC9	2	Underpass	81+620	1 x 7 (W) x 3.5 (H)	Marula- Near Gilgil Junction	New Underpass	Marula
WLC10	2	Underpass	92+040	1 x 5 (W) x 3.50 (H)	Elmenteita-Kariandusi	Maintain Multi-use culvert for wildlife and livestock	N/A
WLC11	2	Overpass	99+380	1 x 30 (W)	Soysambu	New Overpass	N/A
WLC12	2	Underpass	103+285	1 x 5 (W) x 3.5 (H)	Maendeleo-Soysambu	Demolition & reconstruction of a new underpass	Soysambu
WLC13	2	Underpass	104+665	1 x 5 (W) x 3.5 (H)	Soysambu	Demolition and reconstruction of a new underpass	Soysambu
WLC14	2	Underpass	106+215	1 x 5 (W) x 3.5 (H)	Mbaruk - Soysambu	Maintain existing underpass	Soysambu
WLC15	4	Underpass	164+370	1 x 7 (W) x 4.5 (H)	Koibatek Forest - Near Itare Dam	New Underpass for wildlife and livestock	N/A

The cameras were originally meant to be located on both sides of the proposed road in the Soysambu and Marula Estates. However, due to a close proximity to human settlements to the East of Soysambu (Figure 2), the cameras were more prone to vandalism and theft such as camera V13-S marked in red. Hence, the final deployment location for the cameras deployed in Soysambu were nearly all located on the West of the proposed road. In Marula, the cameras were deployed on both East and West of the proposed highway (Mottram et al., 2021). Based on the camera locations we analysed the data using the following by grouping them based on specific sites:

- Soysambu
- Marula East
- Marula West

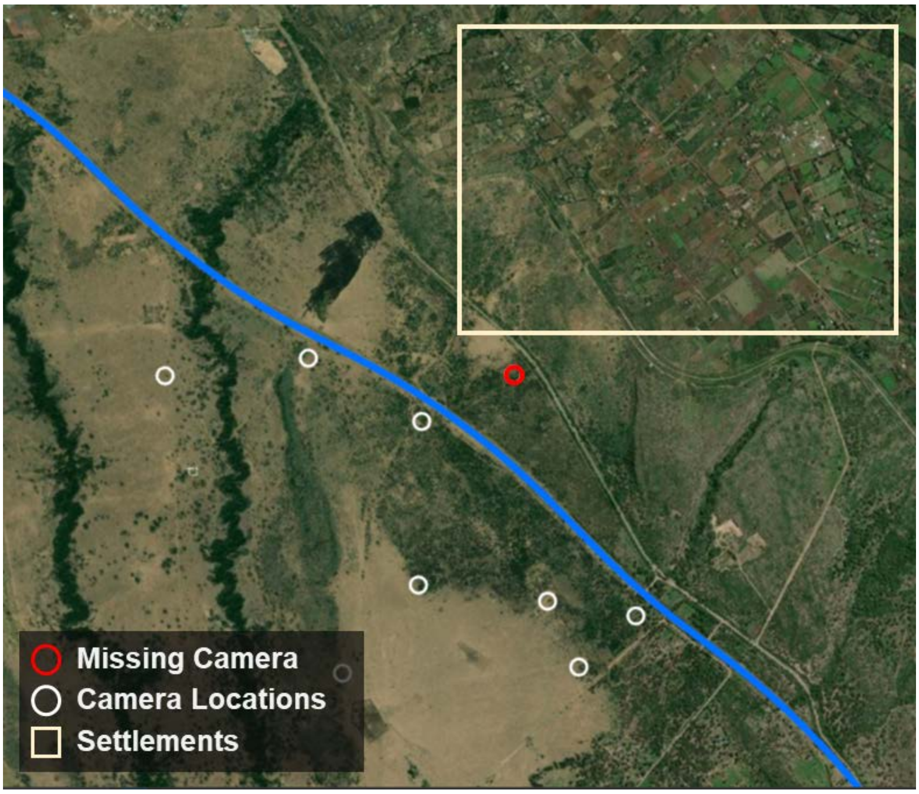

Figure 2: There is a large area of settlement in the top right section (red box) which is the East of the proposed road in Soysambu. The red circle indicates the camera that went missing 4 days after deployment.

2.3.2. Camera setup

The cameras were set to take photos according to two different settings. A time lapse feature was set to automatically trigger an image capture every 15 minutes. In addition, a movement-detection trigger function was also used in parallel (Mottram et al., 2021). To improve the chances of detecting animals, the traps were positioned to maximise the field of vision and focussed on likely movement pathways. The cameras trap images were filtered by WSP using a computer vision algorithm to identify individuals from the four species and the results of this analysis were provided to the University of Nottingham to analyse.

2.4. Camera trap data analysis

2.4.1. Pre-processing

The processing and analysis of the camera data was conducted using R, (Niedballa et al., 2016). The leaflet, dplyr, colortools, kriging, corrplot, lubridate, ggplot2, knitr, rmarkdown, tidyr, splitstackshape, data.table, patchwork, tidyverse, fs and plyr R packages were used to analyse and plot the data.

The data were filtered so that only active camera dates were included in the analysis. Additionally, the data from the camera trap survey was filtered with a 15-minute (original format from WSP) and 30-minute independence threshold, where the maximum number of individuals in a photo was counted. This method of applying a temporal independence threshold is commonly used in the literature to prevent pseudo-replication between captures (Davies et al., 2016; Sollmann, 2018). We used the 30-minute independence threshold for all of our analyses as this is commonly regarded as the best time-interval to address pseudo-replication (Davies et al., 2016; Sollmann, 2018). However, we did include the 15-minute interval analyses in the appendices for completeness. We found the general patterns remained consistent regardless of the interval selected.

The camera detection data provided by WSP included both the occurrence of a species and the count of the number of individuals of a species at each detection, and we analysed both data sets.

We used the following terminology to differentiate between these two kinds of detections:

- Camera detections - Photos with wildlife with one or more individuals detected in a single image - recorded as a single detection.
- Total Individual detections - Count of the total number of individuals for each species within a single image

2.4.2. Types of analyses

We analysed the camera detections and capture rate (i.e. total captures normalised by active days). The data were filtered so that only active camera dates were included in the analysis. The capture rates of each camera was used as a surrogate for abundance (Meek et al., 2012; Sollmann, 2018). The total capture rate was defined as the ratio of independent detection events (i.e. detection events at least 30 min apart) to the number of active camera days (number of 24-h periods during which cameras were operational) and multiplied by 100 days (Rovero and Marshall, 2009).

The formula for calculating capture rates are as follows:

$$Camera\ Capture\ Rate\ per\ day = \frac{Number\ of\ independent\ detection\ events}{Number\ of\ active\ camera\ days\ (Effort)}$$

$$Camera\ Capture\ Rate\ per\ 100\ days = \frac{Number\ of\ independent\ detection\ events}{Number\ of\ active\ camera\ days\ (Effort)} \times 100$$

Total captures and capture rates were analysed for individual cameras and for all cameras combined. However, throughout the study we reported capture rates per 100 days.

We also assessed whether species were more likely to occur together (i.e. whether their detection was correlated) using corrplot within R (Wei and Viliam, 2021). In addition, we assessed species daily activities based on the times when individual species were captured.

2.4.3. Overall capture rate and comparison between wet and dry months

The camera trap data was analysed for the whole time-series and also based on time periods representing seasonal differences. Kenya is considered to have to rainy seasons, from mid-March to June, commonly described as the ‘long rains’, and the ‘short rains’ around November and December. Based on the biodiversity baseline investigation on mammals report conducted by FFMES (Mottram et al., 2021), the study area experiences at least 3 times as much precipitation during the wettest winter months compared to the driest summer months. A bimodal rainfall pattern can be observed with the highest rainfall peaks in April to May (Figure 3). The recorded mean annual rainfall at Naivasha is 677 mm and the mean highest rainfall of 119 mm (April). The 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 2).

Three temporal groups of active cameras trapping dates were derived from the dataset and used for further analysis based on known weather patterns and the FFMES's data:

- Full camera trap survey period (February to June)
- Dry month (February)
- Wet months (March to May)

These dates were chosen to address:

- Overall and interspecific differences in abundances that may be driven by changes in rainfall and temperature patterns due to a species ecology.
- Differences in active camera periods associated with the majority of cameras operating at the beginning of the study and less cameras operating towards the end of the study. The most complete dataset is available from February to March (i.e. the period of time when there was the most number of active cameras).

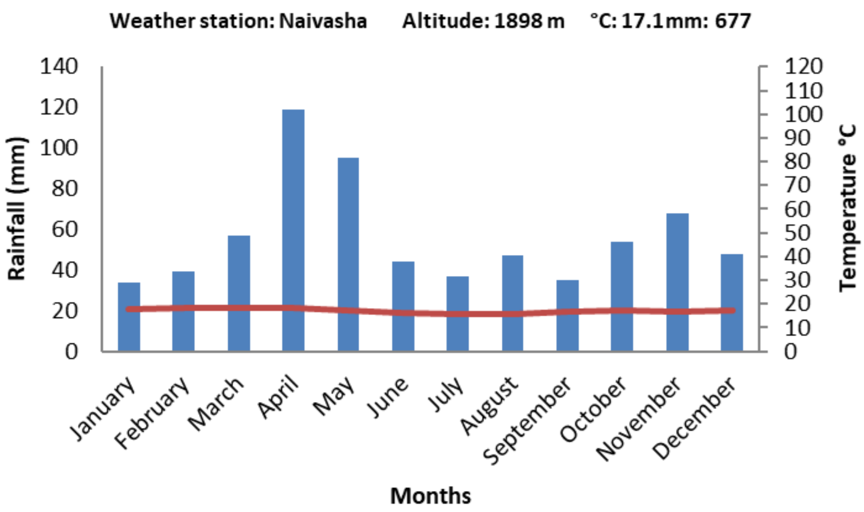

Figure 3: Climatic diagram for Naivasha, Nakuru district, Kenya (Mottram et al., 2021). The blue bars represent the mean monthly rainfall (mm) while the red line indicates the mean monthly temperature (°C).

Table 2: Mean monthly rainfall (mm) and temperatures (°C) for Naivasha, Nakuru district, Kenya (Mottram et al., 2021).

		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

2.5. Spatial analysis

In the final analyses we mapped the capture rates for the full camera trap survey period (February to June), the dry month (February) and wet months (March to May). In addition, we mapped relative abundances of the four species. The locations of the wildlife crossings were also included and compared with the total and species-specific relative abundances at each location.

3.0 Results

3.1. Camera deployment period and activity

While a total of 50 cameras were initially deployed (Figure 4), there were only 48 cameras active at any given date due to the different initial deployment dates and variable functionality of each camera (Figure 5).

The majority of cameras were operational across their deployment period, however, a large number of cameras had inactive periods within their deployment period (Figure 5). The highest number of active cameras (highlighted in green in Figure 5) was 48 cameras on the 26th and 27th of February. The difference between the number of deployed vs active cameras are highlighted in Table 3.

The total sampling period was 113 days, with a combined total of 3415 active camera trap days (Figure 5). The deployment period for each camera can be observed in Figure 4. In Soysambu, Marula West and Marula East there were 15, 17 and 18 cameras deployed respectively. The cameras in Marula west had longer deployment periods compared to other sites.

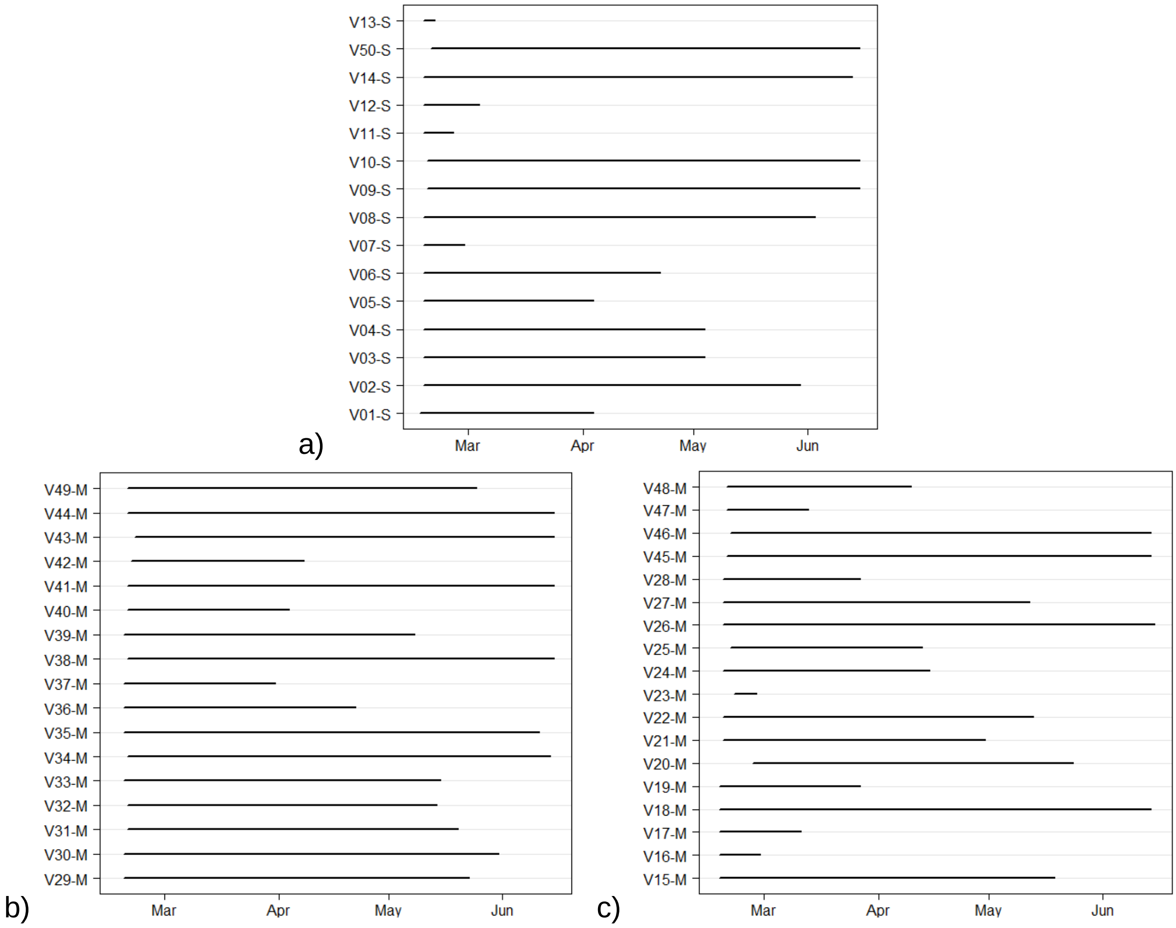

Figure 4: Camera trap deployment period (i.e. only shows start and end dates) for (a) Soysambu (b) Marula West and (c) Marula East.

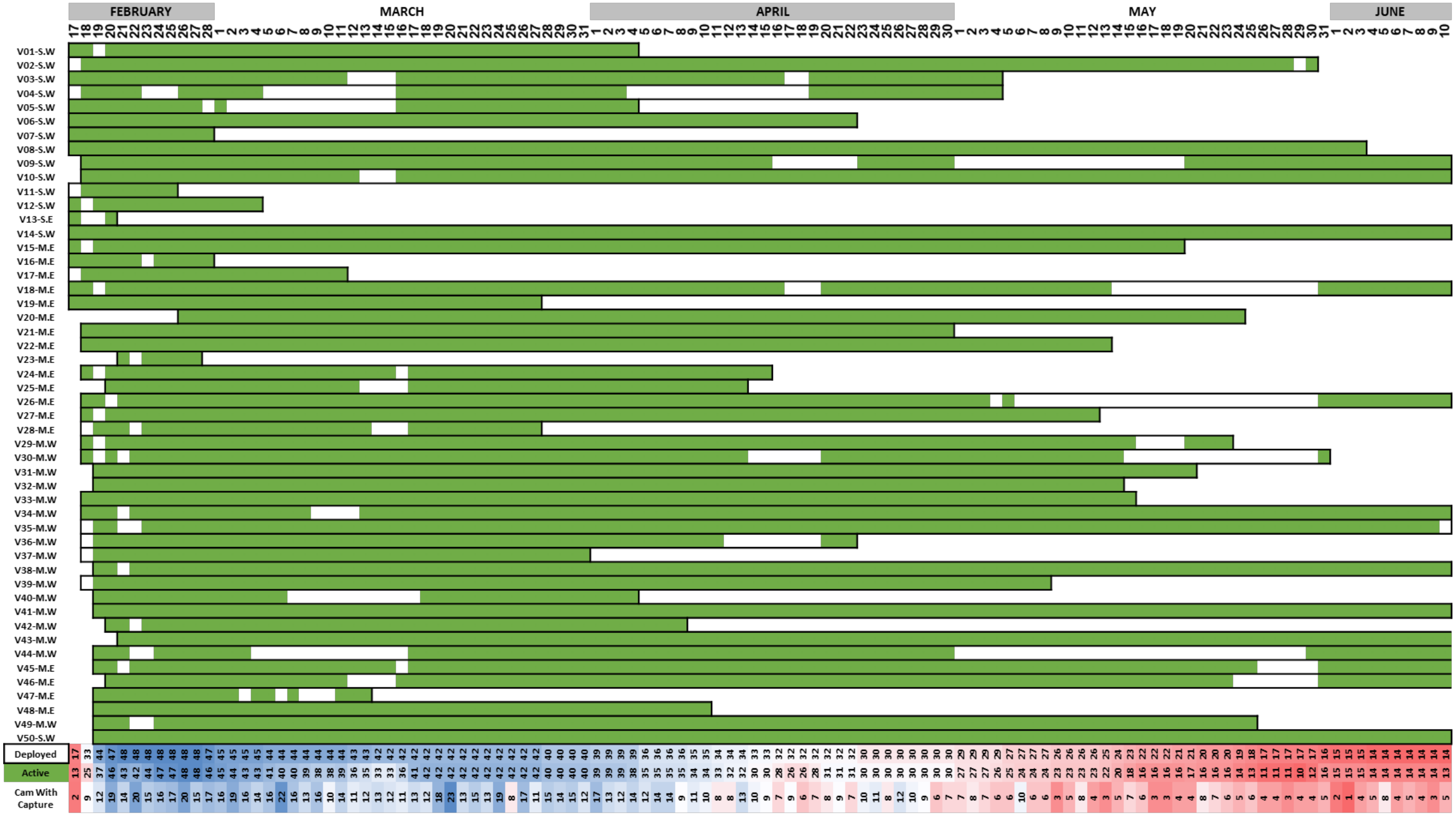

Figure 5: The camera deployment period between 17th February to 10th June (black outline) and the active (green cells) and inactive (white cells) camera days. Note that the 'S' or 'M' at the end of the camera number represents 'Soysambu' and 'Marula' respectively and the '.E' and '.W' represents 'East' and 'West' of the highway. The number of deployed cameras, active cameras and camera with captures have been highlighted with strong to light intensity of blue to red colour scale indicating high to low values and white indicates the median values.

Figure 6 summarises the trends in the total number of deployed and active cameras, and cameras with captures of wildlife at each active date. The number of deployed, active cameras and camera with captures of wildlife within the deployment period decreased over time, from the highest total number of 48 deployed cameras per day in February to 15 or less cameras a day deployed and active in June (Figure 5 and Figure 6).

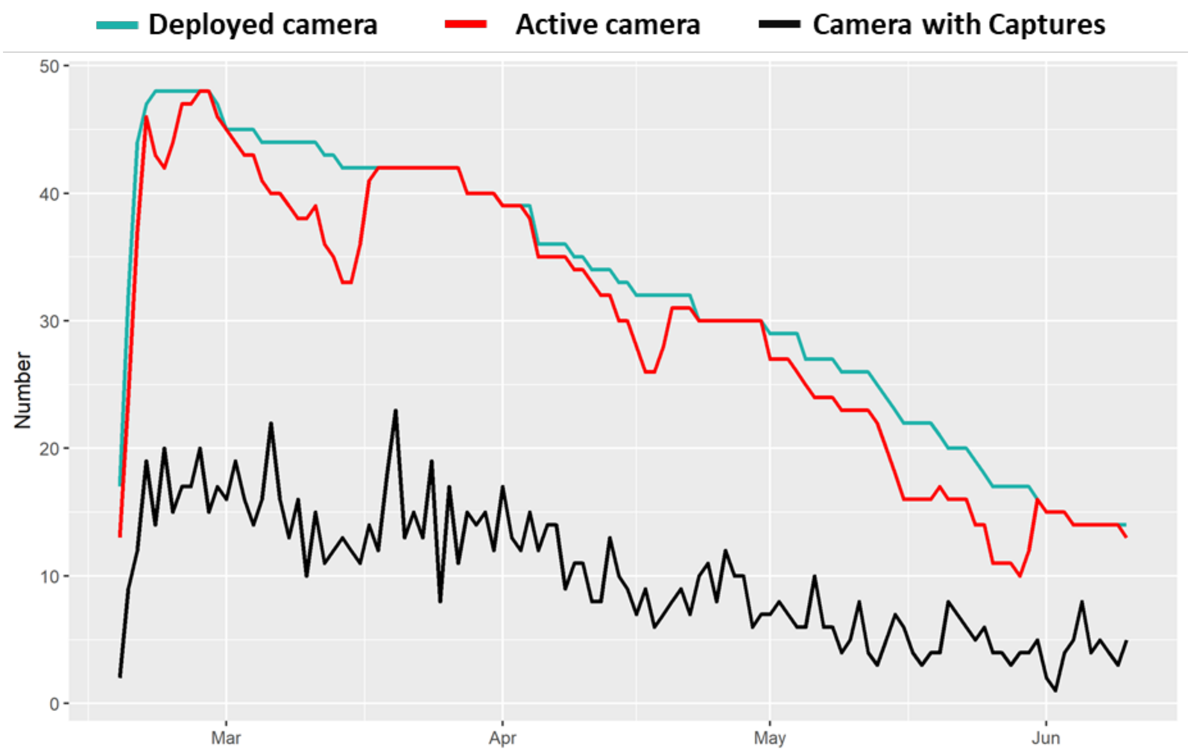

Figure 6: The total number of deployed and active cameras, and cameras with captures at each specific date (See Appendix A for the data for each camera).

Table 3 summarises the total active days for each camera. Cameras V13-S and V23-M were active but never detected any species, most likely because none of the focal species were present near the cameras during the short deployment period. The total number of active days for all other cameras ranged from 8 (V11-S) to 114 (V14-S) days.

Table 3: Details regarding the camera activity of each of the 50 cameras deployed. Cameras V13-S and V23-M that are highlighted in red went missing less than a week after deployment. The difference between the camera's active dates and deployment period are calculated in the 'Difference' column. The colour scales have been ordered based strong to light intensity of blue to red colour indicating high to low values and white indicates the median values. The total species captured were out of the 4 key species.

Camera	Start date	End date	Deployment period (days)	Total number of active days	Difference between deployed and active days	Total number of photos with wildlife captured	Total individuals captured (15min independence)	Total individuals captured (30min independence)	No. of target species captured
V01-S.W	16/2/2021	4/4/2021	47	46	-1	175	307	160	2
V02-S.W	17/2/2021	30/5/2021	103	101	-2	238	440	265	3
V03-S.W	17/2/2021	4/5/2021	77	71	-6	111	186	116	2
V04-S.W	17/2/2021	4/5/2021	77	47	-30	77	153	92	2
V05-S.W	17/2/2021	4/4/2021	47	32	-15	60	93	51	1
V06-S.W	17/2/2021	22/4/2021	65	65	0	139	225	132	1
V07-S.W	17/2/2021	28/2/2021	12	12	0	55	97	51	2
V08-S.W	17/2/2021	3/6/2021	107	107	0	291	515	248	3
V09-S.W	18/2/2021	15/6/2021	113	87	-26	74	126	89	3
V10-S.W	18/2/2021	15/6/2021	113	110	-3	183	339	202	3
V11-S.W	17/2/2021	25/2/2021	9	8	-1	7	14	11	1
V12-S.W	17/2/2021	4/3/2021	16	15	-1	23	29	17	2
V13-S.E	17/2/2021	20/2/2021	4	2	-2	NA	NA	0	NA
V14-S.W	17/2/2021	13/6/2021	114	114	0	100	159	99	2
V15-M.E	17/2/2021	19/5/2021	91	91	0	14	15	14	2
V16-M.E	17/2/2021	28/2/2021	12	11	-1	1	1	1	1
V17-M.E	17/2/2021	11/3/2021	23	22	-1	11	12	9	2
V18-M.E	17/2/2021	14/6/2021	114	93	-21	36	43	37	2
V19-M.E	17/2/2021	27/3/2021	39	39	0	28	39	25	4
V20-M.E	26/2/2021	24/5/2021	88	88	0	40	66	49	3
V21-M.E	18/2/2021	30/4/2021	72	72	0	35	59	36	2
V22-M.E	18/2/2021	13/5/2021	85	85	0	29	39	26	2
V23-M.E	21/2/2021	27/2/2021	7	6	-1	NA	NA	0	NA
V24-M.E	18/2/2021	15/4/2021	57	55	-2	14	20	11	1
V25-M.E	20/2/2021	13/4/2021	53	49	-4	19	36	20	2
V26-M.E	18/2/2021	15/6/2021	113	86	-27	72	137	90	1
V27-M.E	18/2/2021	12/5/2021	84	83	-1	86	194	103	2
V28-M.E	18/2/2021	27/3/2021	38	33	-5	29	46	25	1
V29-M.W	18/2/2021	23/5/2021	95	90	-5	136	236	171	1
V30-M.W	18/2/2021	31/5/2021	103	79	-24	52	89	57	1
V31-M.W	19/2/2021	20/5/2021	91	91	0	32	55	45	3
V32-M.W	19/2/2021	14/5/2021	85	85	0	35	53	39	2
V33-M.W	18/2/2021	15/5/2021	87	87	0	85	185	87	4
V34-M.W	18/2/2021	14/6/2021	113	107	-6	74	116	61	2
V35-M.W	18/2/2021	11/6/2021	113	109	-4	80	135	93	3
V36-M.W	18/2/2021	22/4/2021	64	55	-9	42	61	44	1
V37-M.W	18/2/2021	31/3/2021	42	41	-1	27	47	21	4
V38-M.W	19/2/2021	15/6/2021	112	111	-1	26	33	17	2
V39-M.W	18/2/2021	8/5/2021	80	79	-1	1	2	2	1
V40-M.W	19/2/2021	4/4/2021	45	34	-11	167	477	202	3
V41-M.W	19/2/2021	15/6/2021	112	112	0	84	135	93	3
V42-M.W	20/2/2021	8/4/2021	48	47	-1	6	9	9	1
V43-M.W	21/2/2021	15/6/2021	110	110	0	23	33	24	2
V44-M.W	19/2/2021	15/6/2021	112	68	-44	8	13	13	1
V45-M.E	19/2/2021	14/6/2021	112	105	-7	33	55	38	1
V46-M.E	20/2/2021	14/6/2021	111	100	-11	9	9	9	2
V47-M.E	19/2/2021	13/3/2021	23	18	-5	34	73	34	1
V48-M.E	19/2/2021	10/4/2021	51	51	0	7	7	6	4
V49-M.W	19/2/2021	25/5/2021	96	94	-2	1	1	1	1
V50-S.W	19/2/2021	15/6/2021	112	112	0	177	432	238	3
Total			**3697**	**3415**		**3086**	**5646**	**3283**	

3.2. Number of individuals captured

The total number of wildlife detections (i.e. one or more individuals identified in a single camera image) across the study area for the 4 key species was 1917 (Figure 7a) and a total of 3,283 individuals were detected (Figure 7b). In terms of total number of individuals, the highest number was 2,953 for Zebra and the lowest number was for Hyena at 77 individuals. Additionally, 153 Buffalo individuals and 100 Giraffe individuals were detected. Zebra were detected at the majority of sites (n = 46) and Giraffe were detected at the least number of sites (n = 12) (Figure 7c).

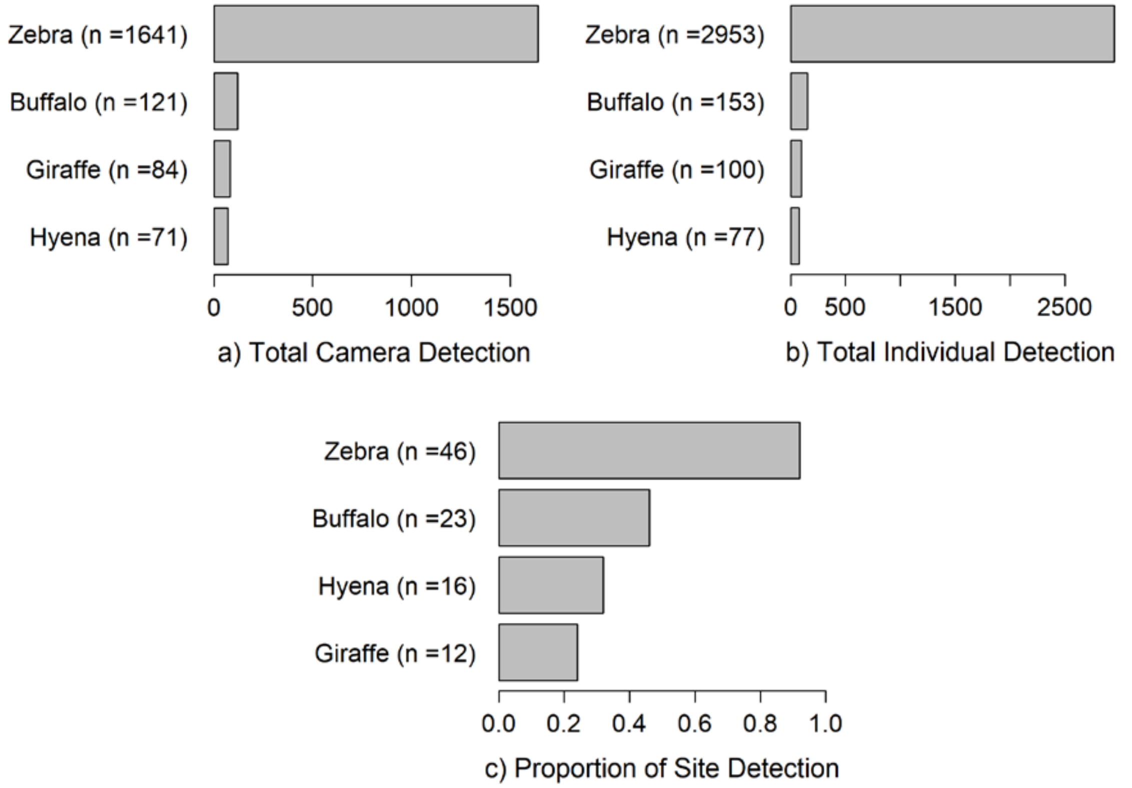

Figure 7: Patterns in the number of detections for (a) species occurrence (photos with one or more individuals, (b) total individual detection and (c) number of sites where each species was detected.

3.3. Site-level species covariance

Figure 8 shows the covariance between different species at the site level. From the survey, we observed that Hyena, Zebra and Buffalo are mostly present at the same locations as indicated by positive covariances. On the other hand, Giraffe are mostly present in areas where other species are less abundant as described by the negative covariance.

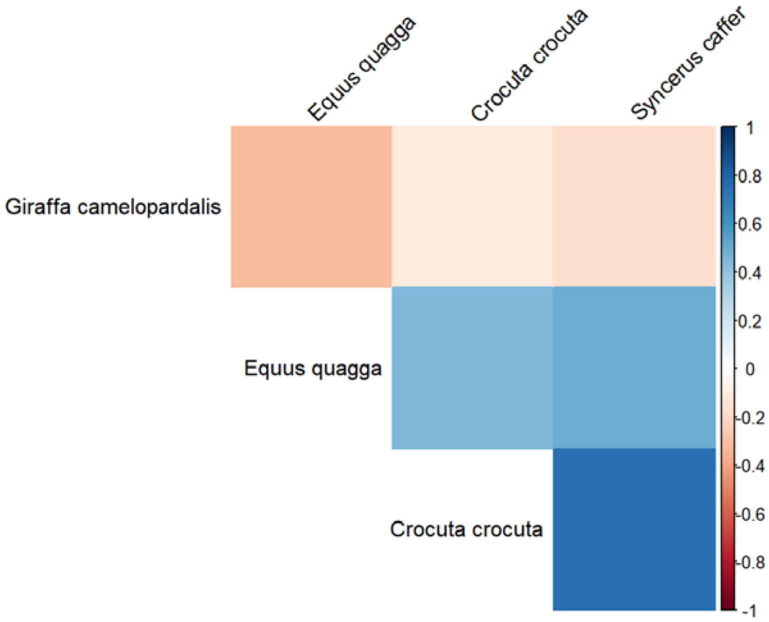

Figure 8: Camera location species covariance.

3.4. Daily patterns in wildlife detections

Figure 9 shows a compilation of daily patterns for all four target species, and includes a comparison of whether daily patterns vary between wet months and the dry month.

Buffalo activity patterns were similar to the observation made by Ryan and Jordaan (2005) where animals are more active during the early morning and night while spending a higher proportion of the day resting. The peaks in the detection of buffalo occurred in the late morning and evening periods. There were less buffalo activity during the afternoon period in the wet months compared to the dry month of February.

Giraffe were present throughout the day in the full deployment period with peaks in detections in the early morning and evenings. As with most other ungulates in the savannahs of Africa, they are active both day and night at varying extents and the activity patterns are interspersed with multiple resting phases (Adolfsson, 2009). Generally, more Giraffe were recorded in the daytime and evening for the wet months. As there were limited number of Giraffe observed during the short dry month period sampled, the results may not accurately depict the actual daily activity of Giraffe in the area.

Zebra were detected throughout the day and night during the full deployment period. The peaks in activity were during the early morning and later afternoon periods similar to Reta and Solomon's (2014) observations. Less evening activities and overall frequency of observations were observed during the wet months.

For Hyena, during the full deployment period, they were only captured during the early morning and at night-time, but never in the late morning and afternoon period. This pattern is similar to the activity patterns observed by Kolowski et al. (2007). There were minimal differences between the wet and dry months.

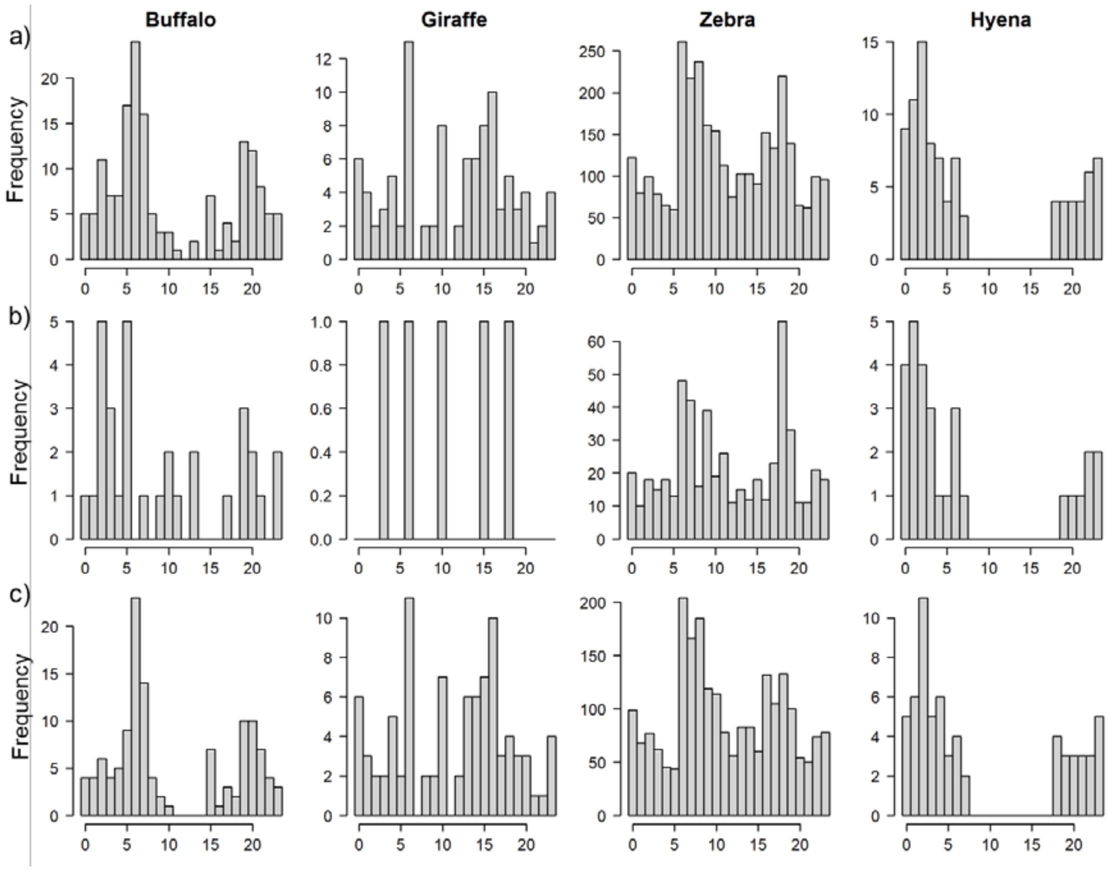

Figure 9: Number of individuals detected of each species for (a) full deployment period, (b) dry month of February and (c) wet months from March to May. The x-axis indicates the hour where 0 is midnight.

3.5. Long-term patterns in wildlife detections

Overall, the number of deployed cameras, active cameras, detections and individuals detected decreased over time (Figure 10). This is not unexpected because cameras became damaged, stolen, or vandalised, batteries went flat and/or malfunctioned for other unknown reasons.

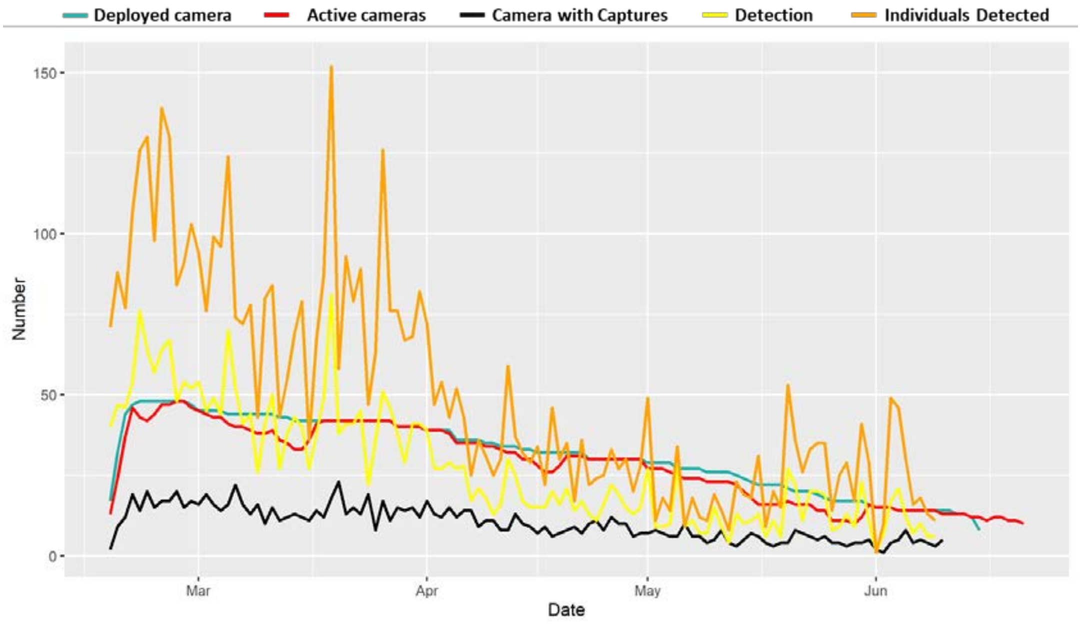

Figure 10: (1) Deployed and (2) active cameras, (3) camera with captures, (4) total number of camera detections and (5) total number of individuals detected per day throughout the deployment period.

The patterns of wildlife detections during the deployment period for the four target species is shown in Figure 11 to Figure 15. Overall, it appears that there were more frequent detections of all four species combined in Soysambu and Marula West than Marula East. For Buffalo, there were more detections in Marula West and Soysambu, though many locations did not include a single detection. Only 4 out of 18 locations in Marula East had Buffalo detections, however, only 1 detection per site. In contrast, Giraffe were mainly found in Marula East, with no detections in Soysambu and almost no detections in Marula West. Zebra had the much higher number of detections compared to the other species and was found across all locations, but with the majority of detections in Marula East and West. Hyena were detected at all three sites but the highest number of detections were at camera V08-S in Soysambu.

The camera location with the highest number of individuals detected was V02-S with 265 total individuals including 253 Zebra, 3 Hyena and 9 Buffalo (Table 4). The highest number of Buffalo at 26 individuals was found at camera V08-S. The highest number of Zebra was at camera location V02-S at 253. The highest number of Hyena was at camera location V08-S at 90. All of these cameras which captured the highest number of Buffalo, Zebra, and Hyena were located in Soysambu. As for Giraffe, the highest number of 21 and 25 individuals were detected at camera locations V18-M and V22-M, both of which were in Marula East.

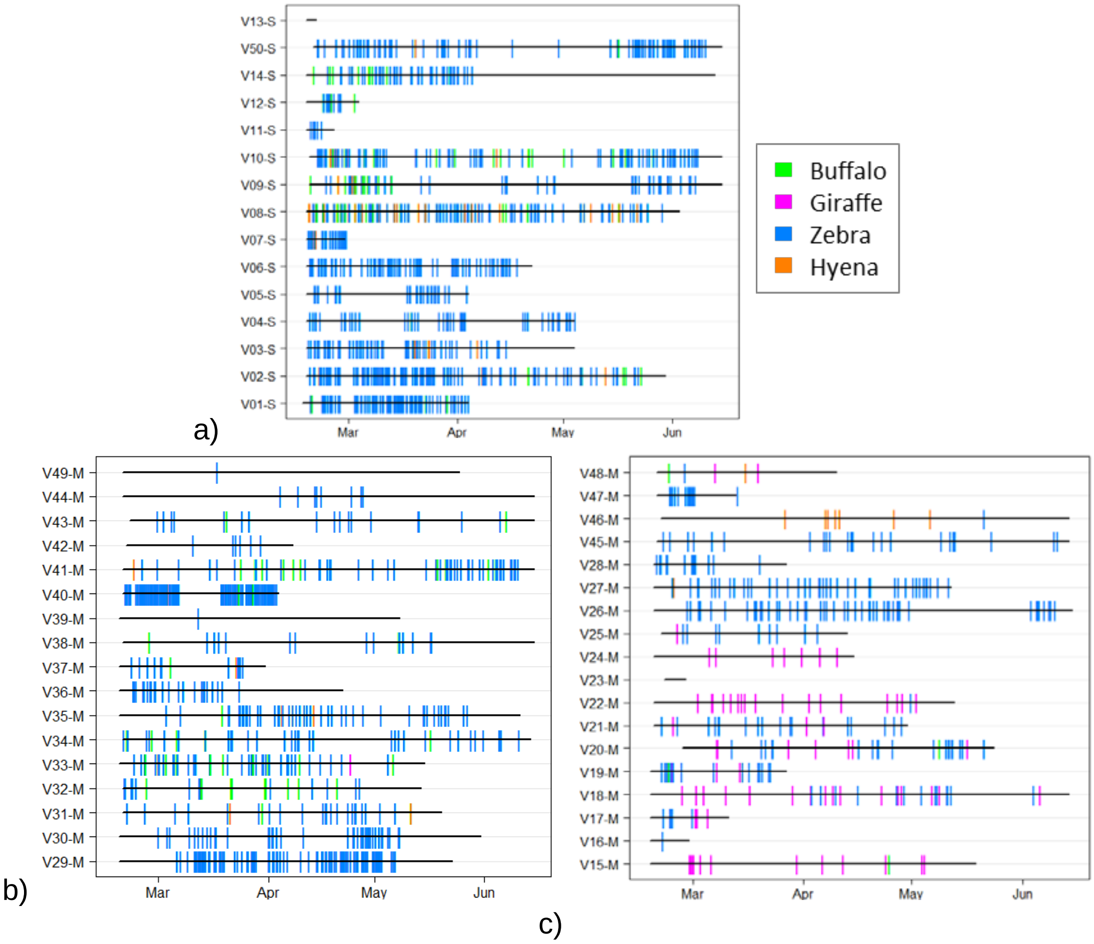

Figure 11: Timing of detections of the four target species in (a) Soysambu, (b) Marula West and (c) Marula East

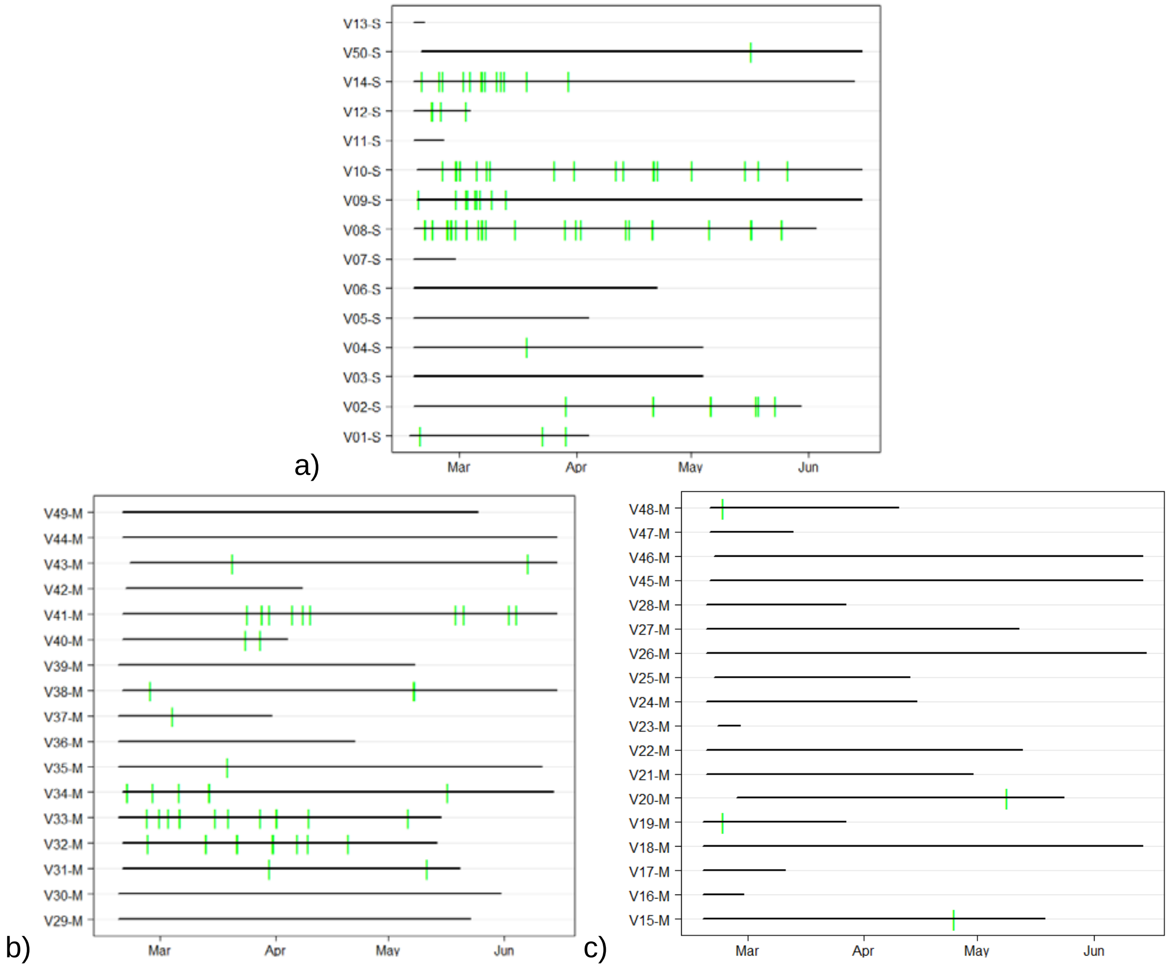

Figure 12: Timing of the detections of Buffalo on cameras in (a) Soysambu, (b) Marula West and (c) Marula East

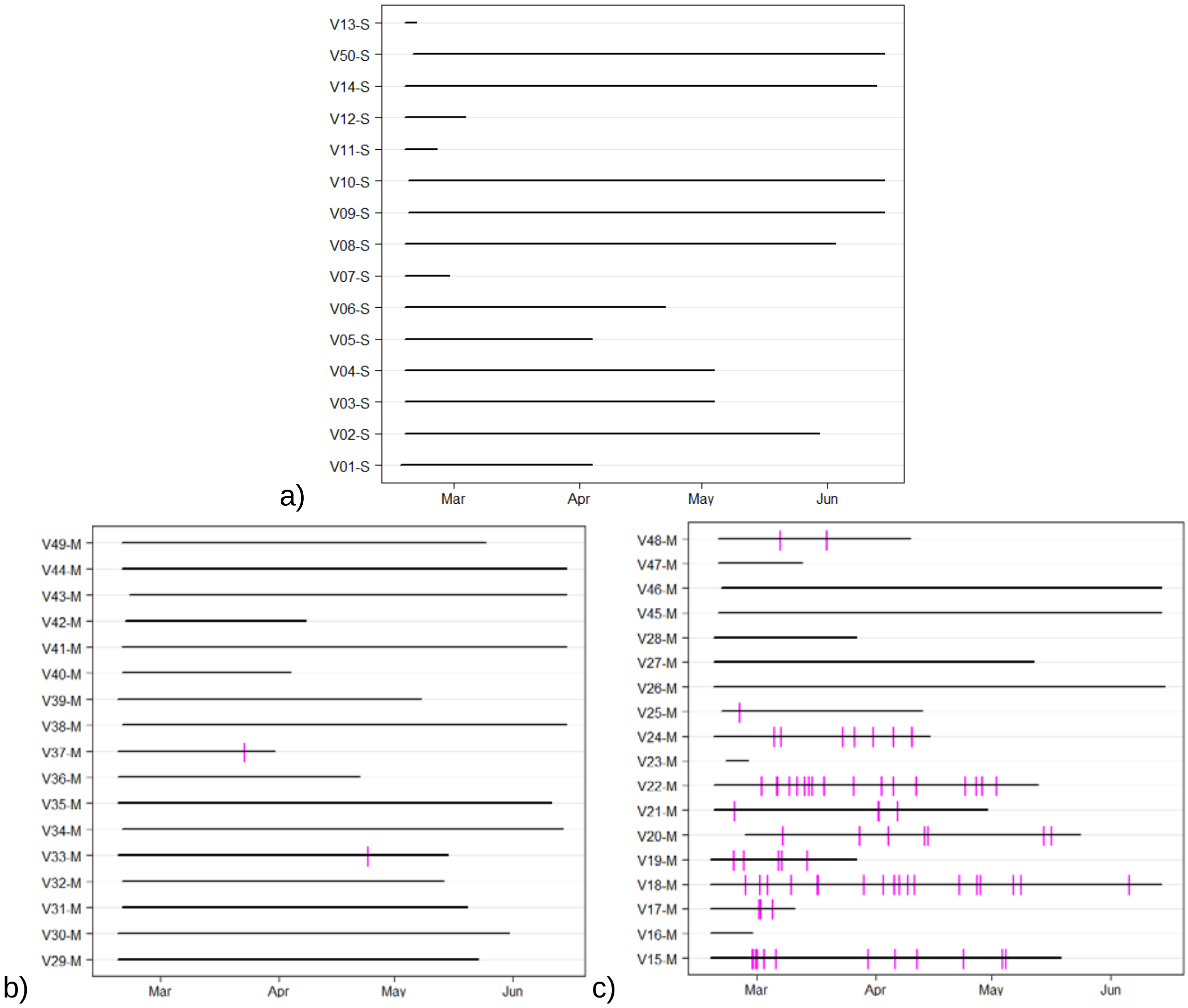

Figure 13: Timing of the detections of Giraffe. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East

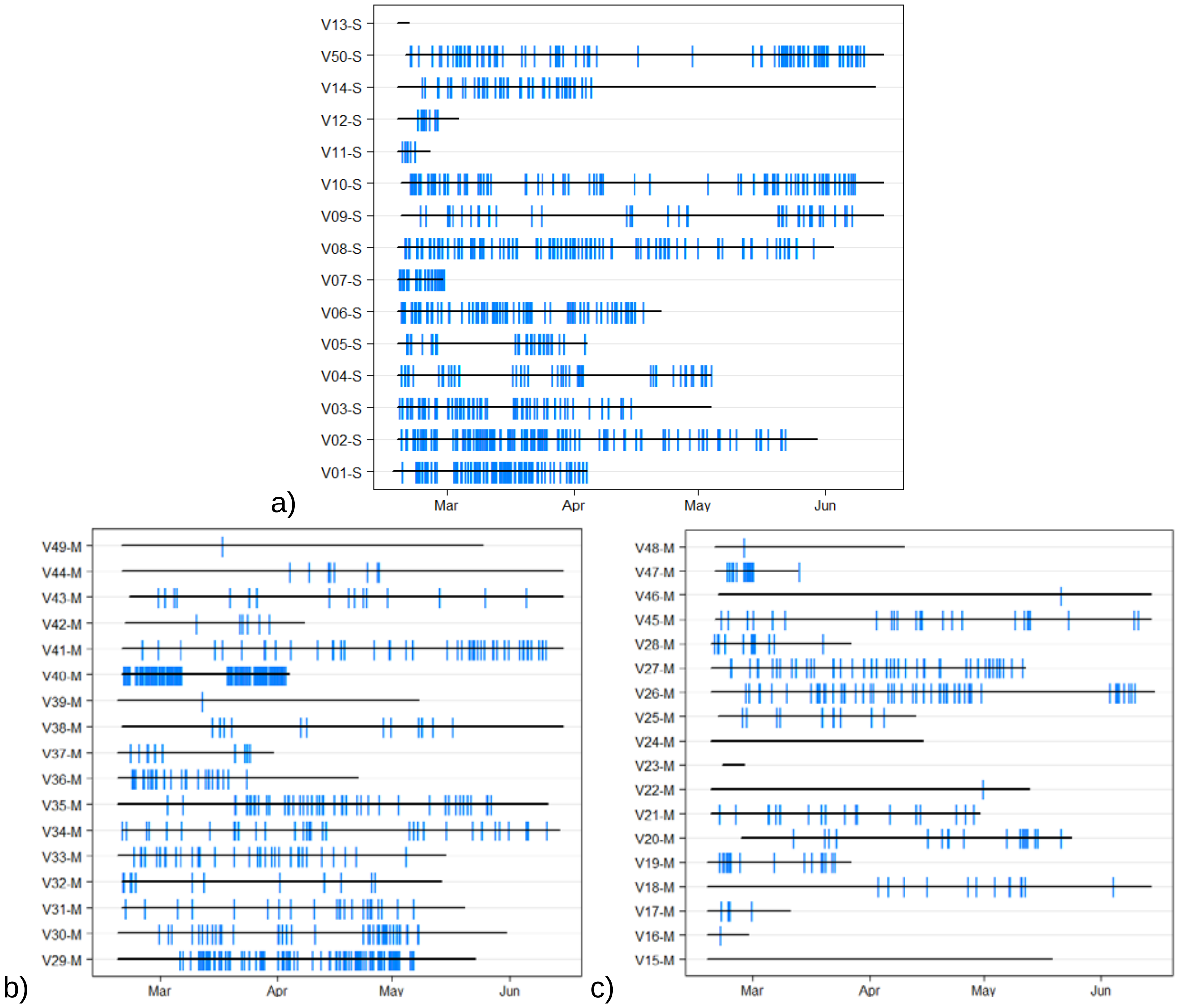

Figure 14: Timing of the detections Zebra. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East

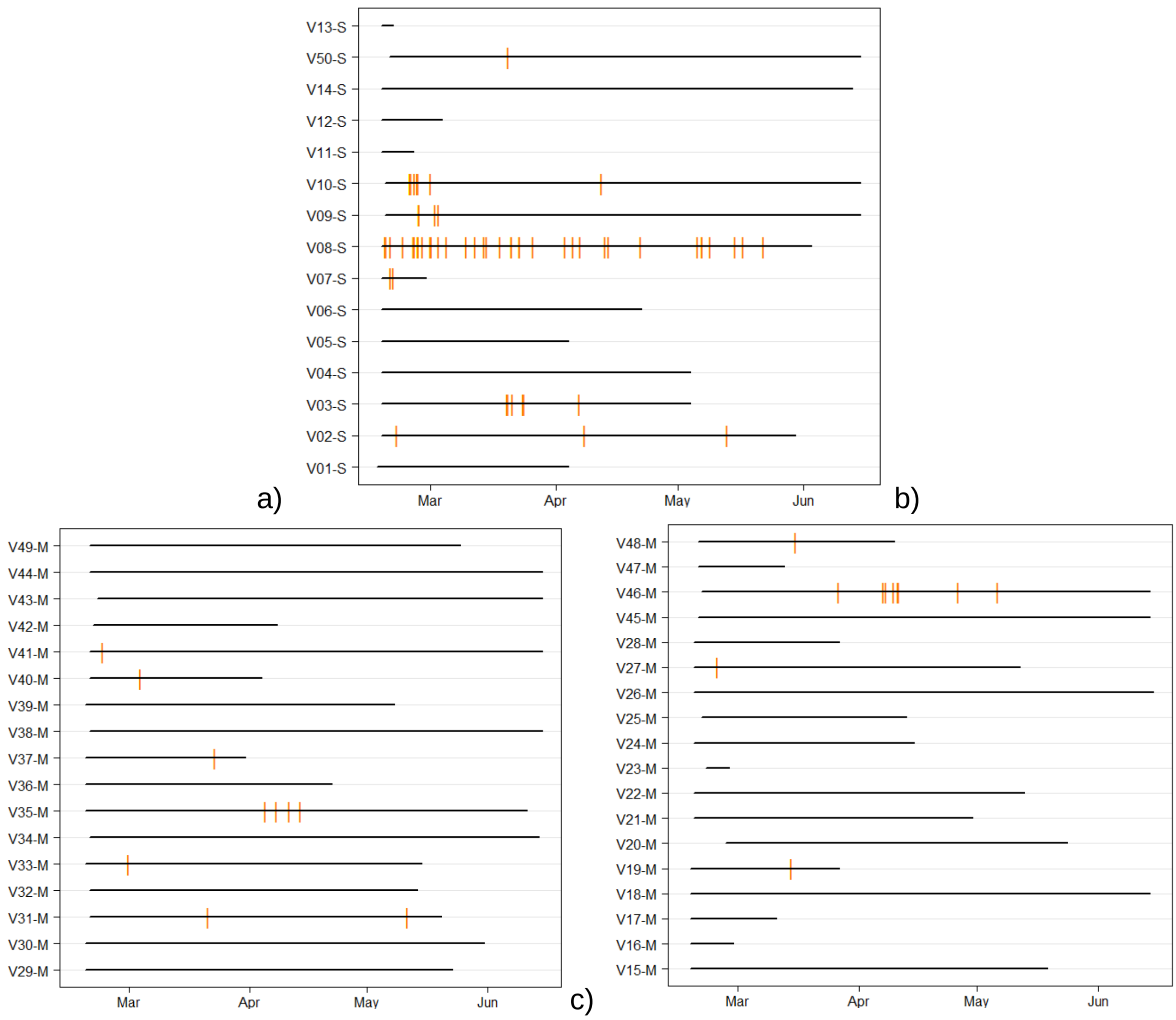

Figure 15: Timing of the detections Hyena. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East

Table 4: Species occurrence, number of individuals detected and rate of detection per 100 days for each camera. Cameras V13-S and V23-M, highlighted in red, went missing less than a week after deployment. The light to dark intensity of white to green highlight indicates lowest to highest values.

Camera	Species Presence					Number of Individuals detected					Detection Rate (per 100 days)				
	Buffalo	Giraffe	Zebra	Hyena	Total No. of Species per Camera	Buffalo	Giraffe	Zebra	Hyena	Total	Buffalo	Giraffe	Zebra	Hyena	Overall Capture Rate
V01-S	1	0	1	0	2	4	0	156	0	160	9	0	339	0	348
V02-S	1	0	1	1	3	9	0	253	3	265	9	0	250	3	262
V03-S	0	0	1	1	2	0	0	110	6	116	0	0	155	8	163
V04-S	1	0	1	0	2	2	0	90	0	92	4	0	191	0	196
V05-S	0	0	1	0	1	0	0	51	0	51	0	0	159	0	159
V06-S	0	0	1	0	1	0	0	132	0	132	0	0	203	0	203
V07-S	0	0	1	1	2	0	0	49	2	51	0	0	408	17	425
V08-S	1	0	1	1	3	26	0	192	30	248	24	0	179	28	232
V09-S	1	0	1	1	3	9	0	76	4	89	10	0	87	5	102
V10-S	1	0	1	1	3	20	0	172	10	202	18	0	156	9	184
V11-S	0	0	1	0	1	0	0	11	0	11	0	0	138	0	138
V12-S	1	0	1	0	2	4	0	13	0	17	27	0	87	0	113
V13-S	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
V14-S	1	0	1	0	2	15	0	84	0	99	13	0	74	0	87
V15-M	1	1	0	0	2	1	13	0	0	14	1	14	0	0	15
V16-M	0	0	1	0	1	0	0	1	0	1	0	0	9	0	9
V17-M	0	1	1	0	2	0	4	5	0	9	0	18	23	0	41
V18-M	0	1	1	0	2	0	21	16	0	37	0	23	17	0	40
V19-M	1	1	1	1	4	2	4	18	1	25	5	10	46	3	64
V20-M	1	1	1	0	3	2	13	34	0	49	2	15	39	0	56
V21-M	0	1	1	0	2	0	3	33	0	36	0	4	46	0	50
V22-M	0	1	1	0	2	0	25	1	0	26	0	29	1	0	31
V23-M	NA	NA	NA	NA	NA	0	0	0	0	NA	NA	NA	NA	NA	NA
V24-M	0	1	0	0	1	0	11	0	0	11	0	20	0	0	20
V25-M	0	1	1	0	2	0	1	19	0	20	0	2	39	0	41
V26-M	0	0	1	0	1	0	0	90	0	90	0	0	105	0	105
V27-M	0	0	1	1	2	0	0	102	1	103	0	0	123	1	124
V28-M	0	0	1	0	1	0	0	25	0	25	0	0	76	0	76
V29-M	0	0	1	0	1	0	0	171	0	171	0	0	190	0	190
V30-M	0	0	1	0	1	0	0	57	0	57	0	0	72	0	72
V31-M	1	0	1	1	3	2	0	42	1	45	2	0	46	1	49
V32-M	1	0	1	0	2	10	0	29	0	39	12	0	34	0	46
V33-M	1	1	1	1	4	14	1	72	0	87	16	1	83	0	100
V34-M	1	0	1	0	2	6	0	55	0	61	6	0	51	0	57
V35-M	1	0	1	1	3	1	0	86	6	93	1	0	79	6	85
V36-M	0	0	1	0	1	0	0	44	0	44	0	0	80	0	80
V37-M	1	1	1	1	4	1	1	18	1	21	2	2	44	2	51
V38-M	1	0	1	0	2	3	0	14	0	17	3	0	13	0	15
V39-M	0	0	1	0	1	0	0	2	0	2	0	0	3	0	3
V40-M	1	0	1	1	3	2	0	199	1	202	6	0	585	3	594
V41-M	1	0	1	1	3	16	0	76	1	93	14	0	68	1	83
V42-M	0	0	1	0	1	0	0	9	0	9	0	0	19	0	19
V43-M	1	0	1	0	2	2	0	22	0	24	2	0	20	0	22
V44-M	0	0	1	0	1	0	0	13	0	13	0	0	19	0	19
V45-M	0	0	1	0	1	0	0	38	0	38	0	0	36	0	36
V46-M	0	0	1	1	2	0	0	1	8	9	0	0	1	8	9
V47-M	0	0	1	0	1	0	0	34	0	34	0	0	189	0	189
V48-M	1	1	1	1	4	1	3	1	1	6	2	6	2	2	12
V49-M	0	0	1	0	1	0	0	1	0	1	0	0	1	0	1
V50-S	1	0	1	1	3	1	0	236	1	238	1	0	211	1	213
Average Capture Rates											4	3	96	2	105
Total Individuals and Capture Rates						153	100	2953	77	**3283**	4	3	86	2	96
						3283					96				

3.6. Capture rate over time

The monthly capture effort and capture rates per 100 days for all species are shown in Figure 16. The dry month of February had a higher capture rate compared to the wet months of March to May. Looking at the trends per species (Figure 17), Buffalo had the highest rate of detection during the dry month which decreased moving towards the wet period but increased again in May at the end of the wet period but decreased again in June. On the other hand, Giraffe showed an increase in the rate of detection for the wet months of March and April which then dramatically and continuously decreased post April. For Zebra, there were more individuals detected during the dry February month which slowly decreased up until to the wet months but increased again in June. For Hyena, the trend shows that the rate of detection decreases over time from the dry February month and increased slightly from the wet March month but ultimately decreased post April.

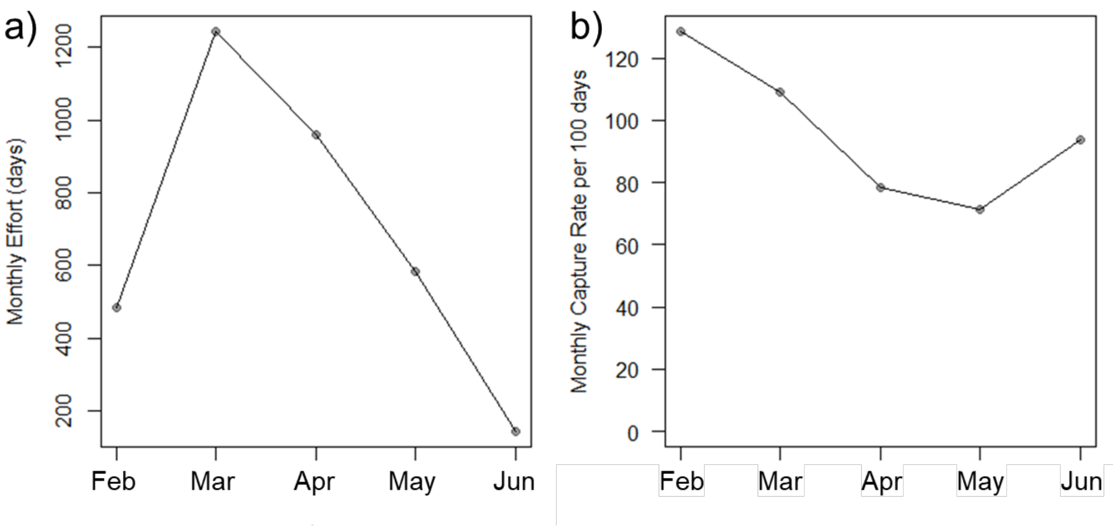

Figure 16: (a) The total monthly number of active days for all cameras (monthly effort) and (b) the number of individuals detected per 100 days for all species combined. February is designated as the dry month while March to May are the wet months.

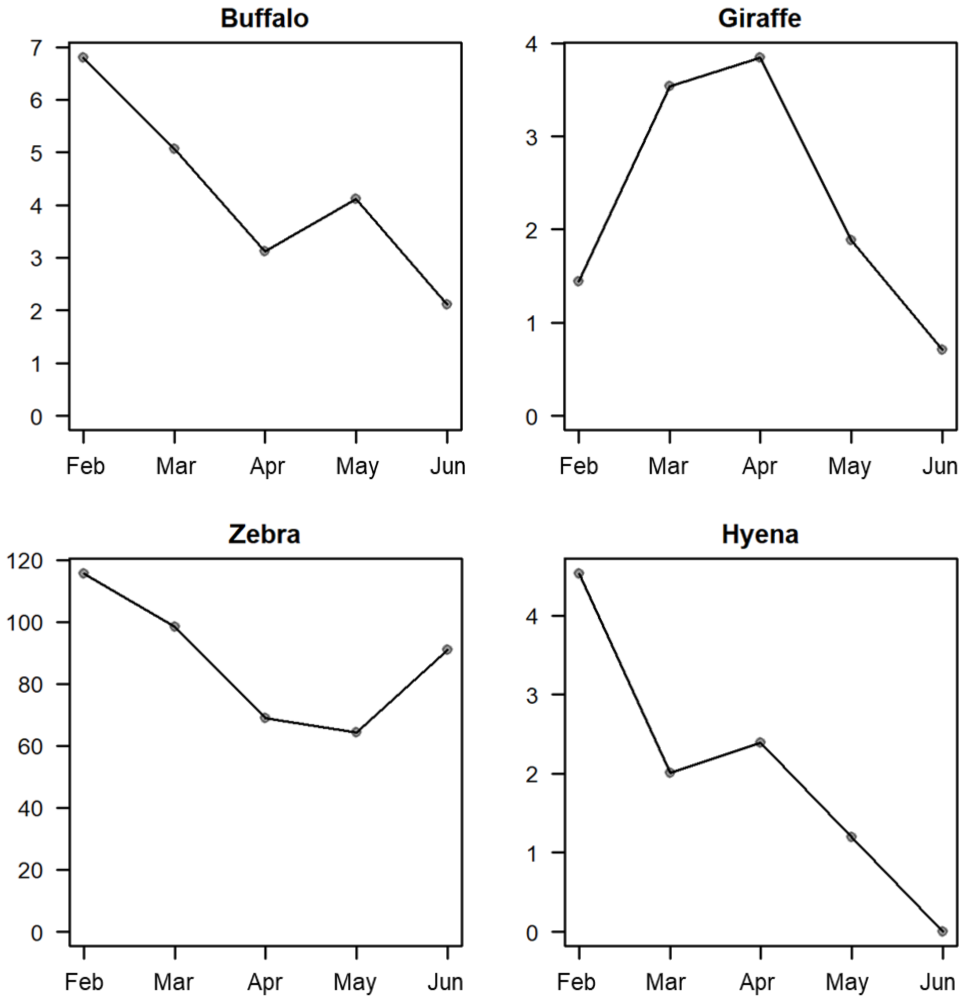

Figure 17: Species-level variation in monthly capture rate per 100 days calculated from the overall deployment individual detections. February is designated as the dry month, while March to May are the wet months. Note the different scale on the Y-axis among species.

3.7. Rate of wildlife detections during wet and dry months

Overall, there was a decreasing trend in the overall capture rate during the wet months from March to May. Despite the lowest number of active camera available during June (Figure 5, Figure 6 and Figure 18), it recorded one of the highest capture rates. The total capture rate was highest during the months of March and June peaking at 1.90 capture rate per day on the 20th of March and 2.07 on the 4th of June. The month with the overall lowest capture rate was in May. Overall, the dry month of February recorded the highest capture rate per 100 days of 128.5 compared to 90.6 for the wet months of March to May (Figure 19).

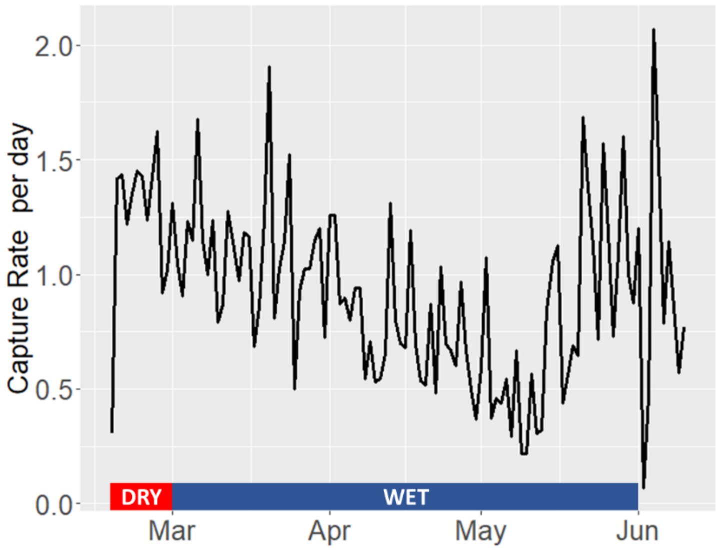

Figure 18: Daily capture rate over time for the full camera deployment period.

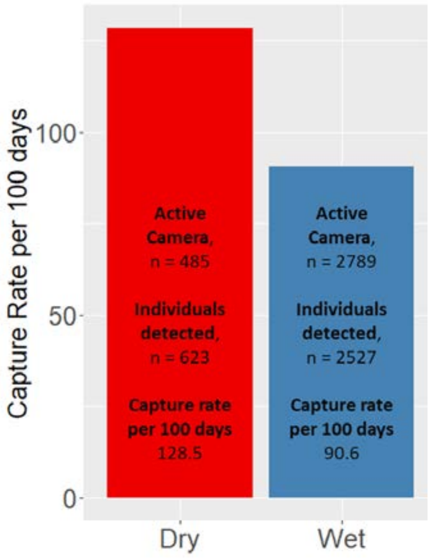

Figure 19: Capture rate per 100 days for Dry (February), Wet (March to May). Active camera days, individual detected and capture rate per 100 days.

3.8. Spatial assessment of capture rates

To examine the spatial and temporal patterns in the rates of wildlife detection we plotted a series of figures which describe the per camera total capture rates (Figure 20), differences in detection rates per species (Figure 21) and capture rates per species over time (Figure 22, Figure 23, Figure 24 and Figure 25). In appendix G, we provide alternative representations to support interpretation. Capture rates are described in terms of capture rate per 100 days and also use the 30-minute interval data.

Overall, majority of the cameras in Soysambu had higher capture rates compared to Marula with the majority of the cameras in Soysambu having twice as high capture rates above 200 (Figure 20). Marula East had the lowest rates of all the sites. Interestingly, certain locations in both Soysambu and Marula had unusually high or low numbers (i.e. V09-S in Soysambu, and V29-M, V27-M, V33-M, and V47-M in Marula). Camera V40-M in Marula West had one of the highest capture rates among the three sites.

In terms of the differences in rate of detection among species, the Zebra tended to be the dominant species across all camera traps and Marula East had the greatest diversity of species (Figure 21). This is especially the case for certain location in Marula East (V46-M, V24-M, V22-M, V17-M, V-18-M, V48-M, V15-M). In Marula East, Giraffe were in some locations the most dominant species (V24-M, V22-M, V-18-M, V48-M, V15-M), while rarely found in Marula West and never found in Soysambu.

Capture rates were higher in the driest month of February rather than wetter months across the study area (Figure 22). For some locations the difference between months was more than double (V40-M, V08-S; Figure 22). This was not consistent across the whole study area. For example, where those differences were reversed (i.e. higher capture rates in wetter months versus drier months) the capture rates were low (i.e. V30-M, V27-M) and thus this may be due to sample size. It is important to note that overall capture rates for Zebra increased in June, but during that time there were very few active cameras (Figure 17).

In terms of patterns of capture rates per species over time, the capture rates seem relatively consistent, especially for camera locations which had high capture rates. As would be expected those cameras with lower sample tended to fluctuate more between time periods (Figure 23, Figure 24 and Figure 25). Zebra tended to dominate over all time periods and locations. For better visualisation of the other species see Appendix G.

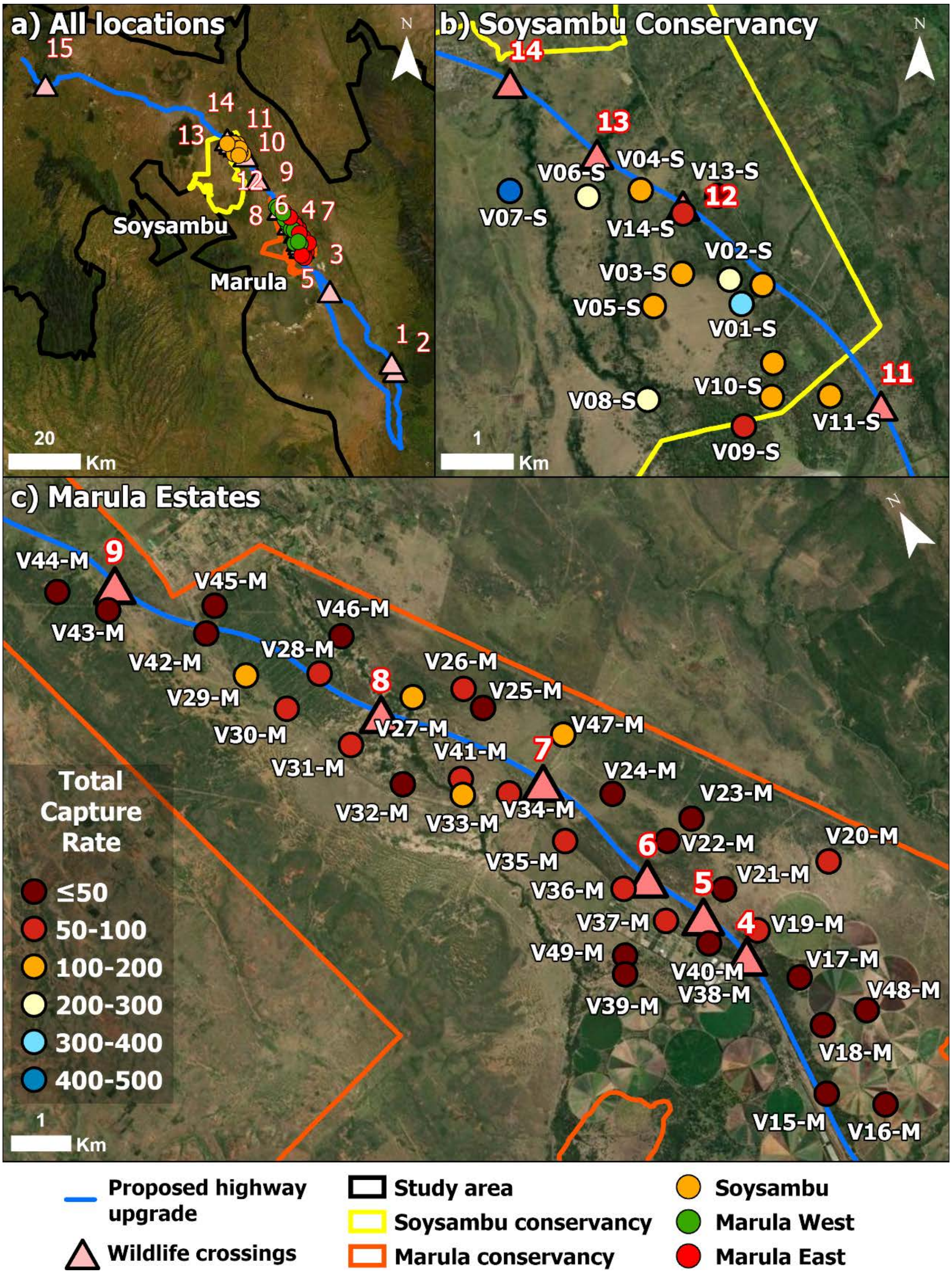

Figure 20: Study area map with the camera trap locations highlighted with colour scales based on the capture rate per 100 days. (a) overall location with reference to the proposed highway, (b) Soysambu, and (c) Marula West and East.

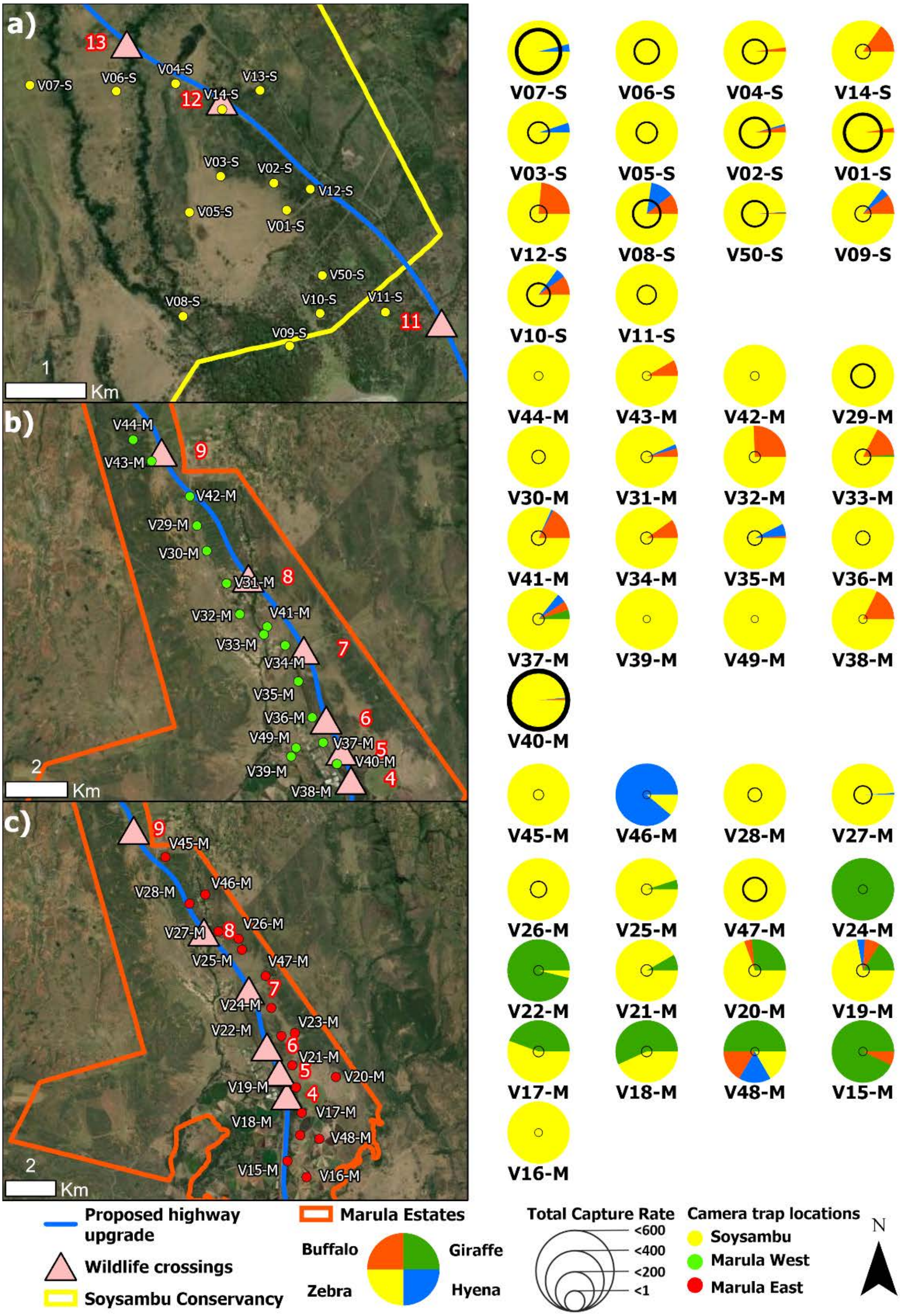

Figure 21: Comparison of total capture rate and capture rates for each species per camera. Figures have been divided based on the camera trap location in (a) Soysambu, (b) Marula West and (c) Marula East.

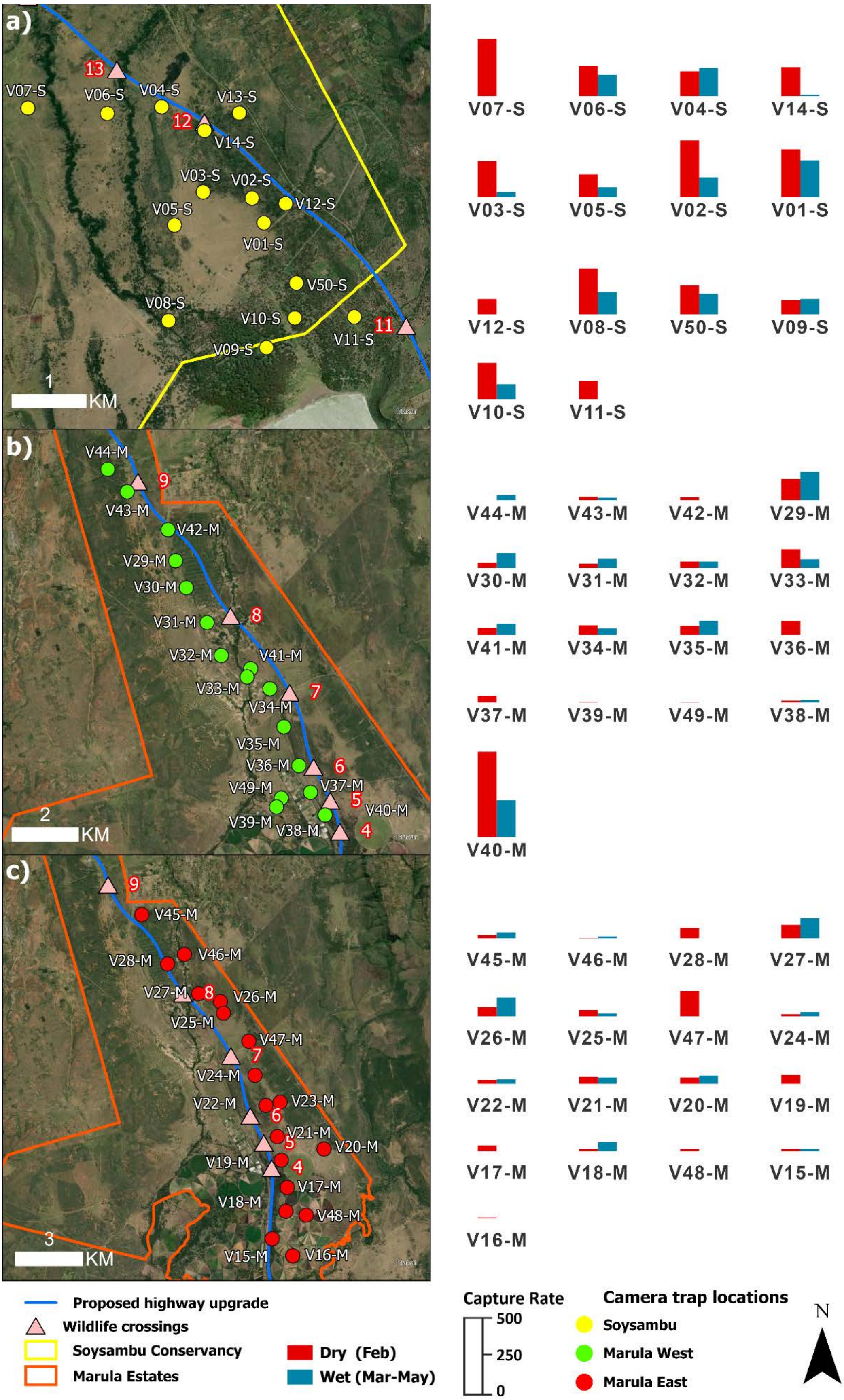

Figure 22: Comparison between dry and wet months (and the remaining months) for capture rate per 100 days for each camera in (a) Soysambu, (b) Marula West and (c) Marula East.

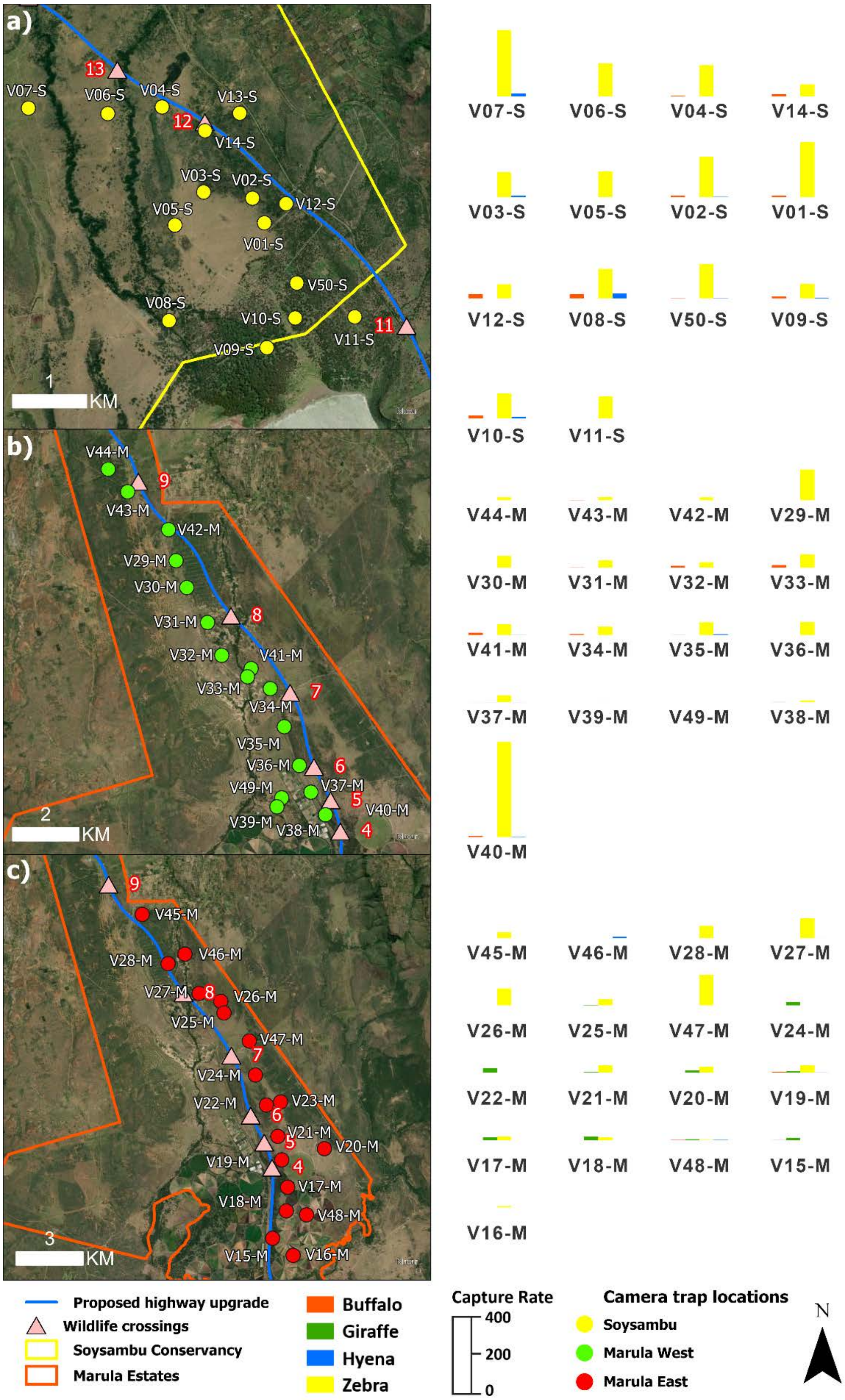

Figure 23: Capture rate per 100 days for the whole camera deployment period per species for each camera in (a Soysambu, (b) Marula West and (c) Marula East.

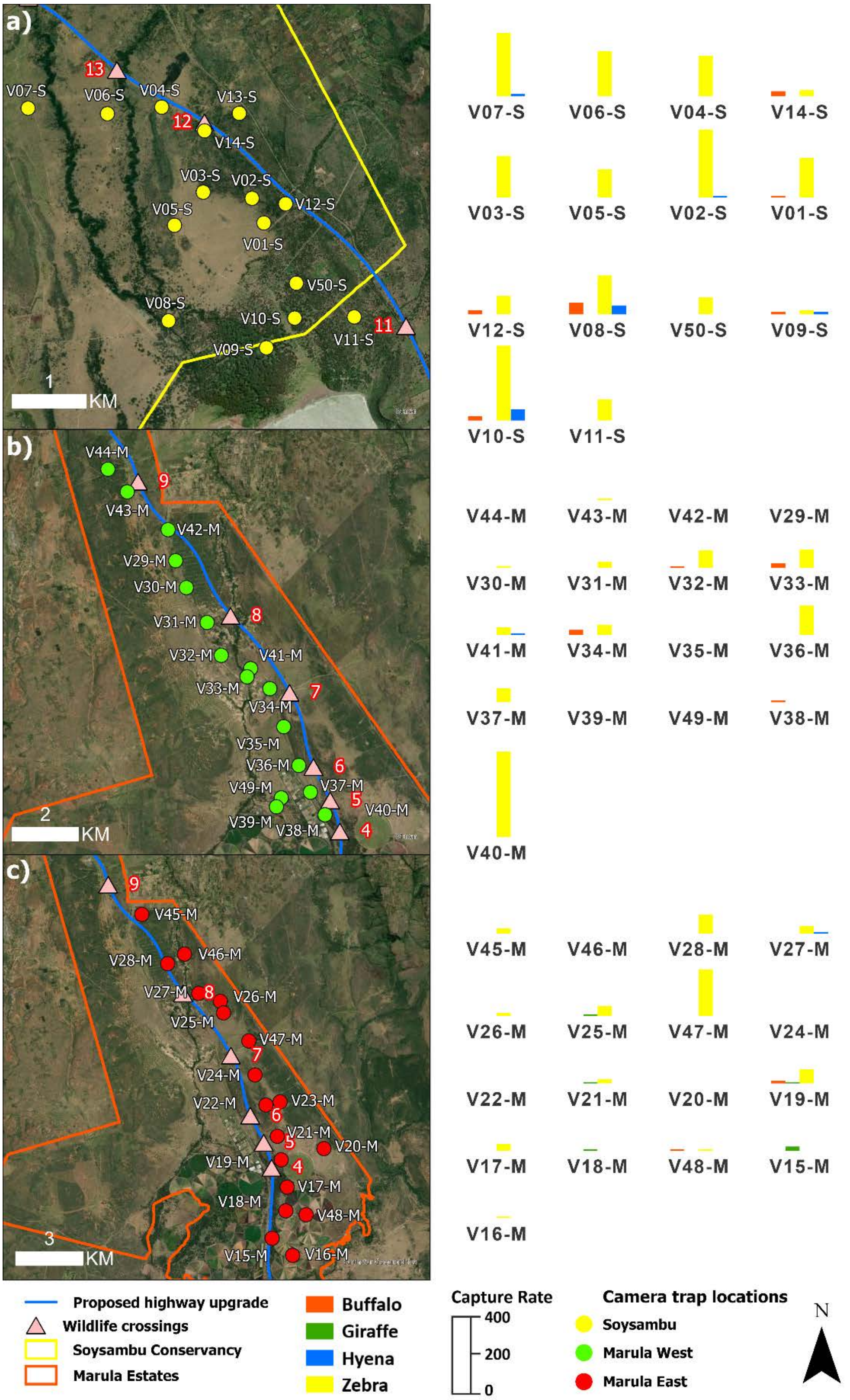

Figure 24: Capture rate per 100 days for the dry month (February) per species for each camera in (a) Soysambu, (b) Marula West and (c) Marula East.

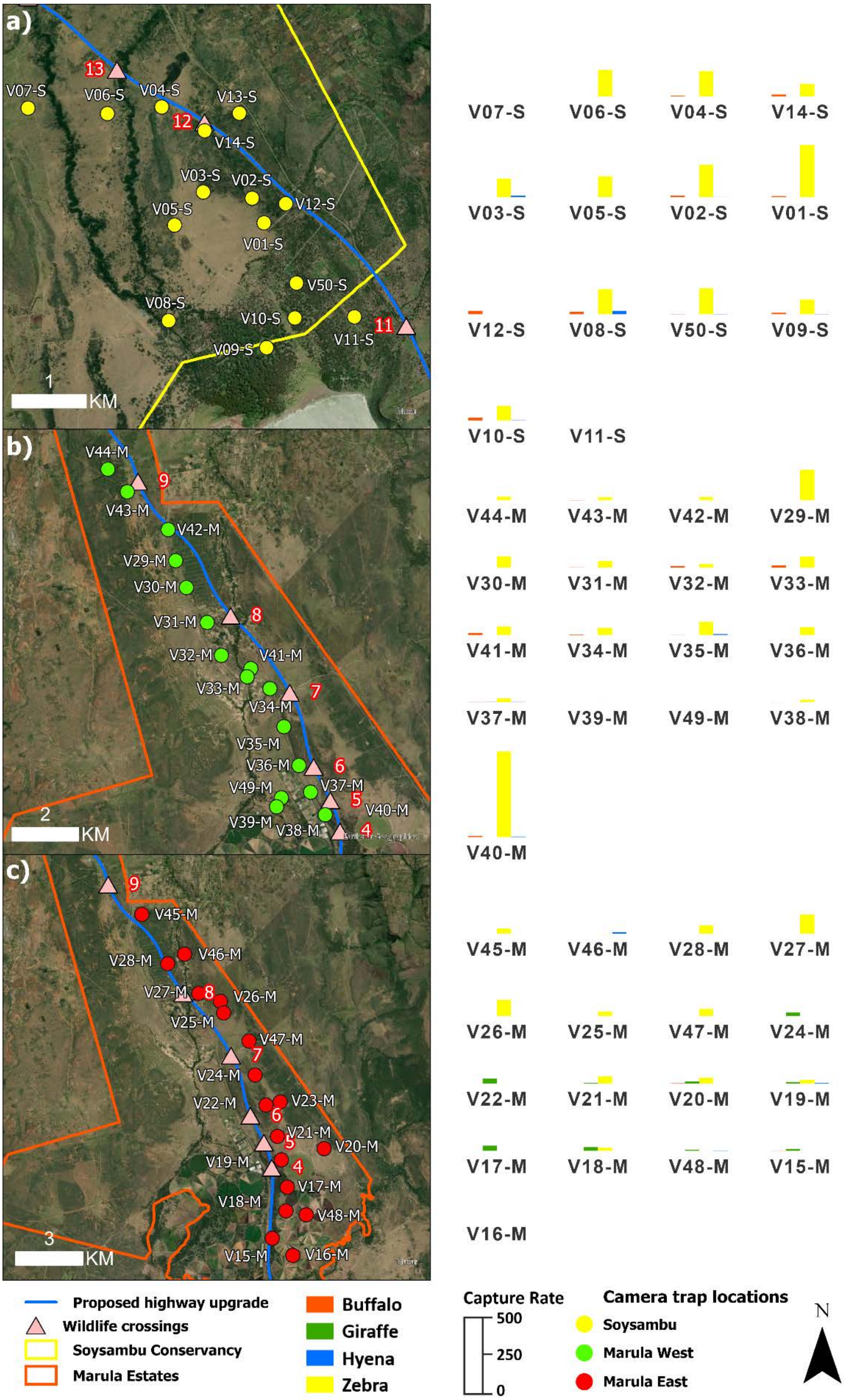

Figure 25: Capture rate per 100 days for the wet months (March to May) per species for each camera in (a) Soysambu, (b) Marula West and (c) Marula East.

4.0 Final Summary and limitations

4.1. Capture rates and wildlife crossing locations

From Figure 21 and Table 3 the top 3 cameras with the highest total capture rates were V40-M, V07-S and V01-S, and the nearest wildlife crossings (WLC) were WLC 5, 12 and 13 respectively. However, V07-S and V01-S were over 1 km away from their respective WLC. Camera V40-M is located in the immediate vicinity, less than 500m, to WLC 5 (Figure 20, Table 4) as well as within ~1km from WLC 4 and WLC 6. Table 4 describes the cameras with the top 2 highest capture rates per 100 days camera trap locations for each species and all species and the nearest wildlife crossing.

Table 4: Top 2 highest capture rates per 100 days camera trap locations for each species and all species and the nearest wildlife crossing. Cameras are colour coded to identity cameras * these cameras were not very near (i.e. greater than 1 km) a specific wildlife crossing.

Camera	Buffalo	Giraffe	Zebra	Hyena	Overall Capture Rate	Location	Nearest Wildlife crossing(s) (WLC)
V12-S	27	0	87	0	113	Soysambu	11*
V08-S	24	0	179	28	232	Soysambu	10*, 11*
V22-M	0	29	1	0	31	Marula East	6
V18-M	0	23	17	0	40	Marula East	4* (Note this is an underpass)
V40-M	6	0	585	3	594	Marula West	5
V07-S	0	0	408	17	425	Soysambu	12*
V08-S	24	0	179	28	232	Soysambu	10*, 11*
V07-S	0	0	408	17	425	Soysambu	12*
V40-M	6	0	585	3	594	Marula West	5
V07-S	0	0	408	17	425	Soysambu	12*

4.2. Other considerations and limitations

The camera trap data provides a good indication of the species found and their abundance at specific locations in the local assessment area. However, it is important to note that the number of active cameras decreases over time so all locations are not equally well sampled and also there appeared to be some impact of wet and dry months on recorded detections which may be driven by the relationship between species and climate. However, due to the limited number of dry months sampled, comparison between the wet and dry months is difficult. When comparing between locations, it is also important to note that the cameras in Marula are near the road while in Soysambu these cameras are located further away from the road, hence some of the differences between the two sites may be driven by road avoidance behaviour.

The camera trap data was provided by WSP and therefore this analysis does not consider or justify the deployment locations and the species chosen for the analysis. Also, the identification of species from camera imagery was conducted by WSP and therefore any issues around detection accuracies was not considered quantitatively in the analysis. There is potential for further analyses to incorporate more sophisticated statistical methods for accounting for detectability and survey effort, and also species behaviour, such as whether there are observable changes in browsing behaviour between wet and dry months and interspecies interactions within images (i.e. individuals of different species found in the same images). However, such analyses are beyond a study conducted for an ESIA.

4.3. Final remarks

These data provide useful support for guiding the assessing and selection of wildlife crossing areas for mitigating the impact of the road on connectivity. The data need to be considered within the context of other datasets, expert knowledge, local topography and the design of the road.

5.0 References

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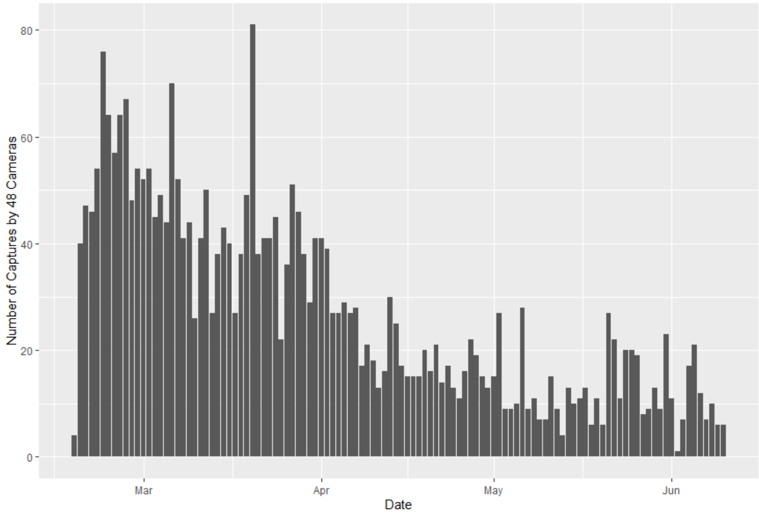
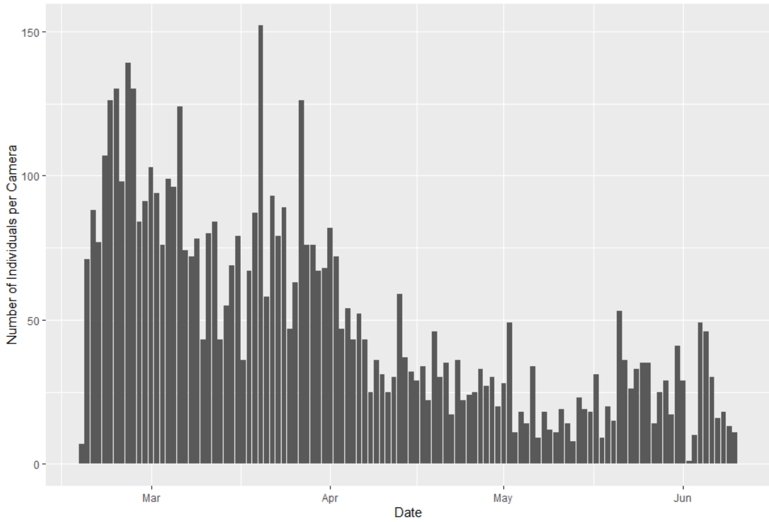
6.0 Appendix

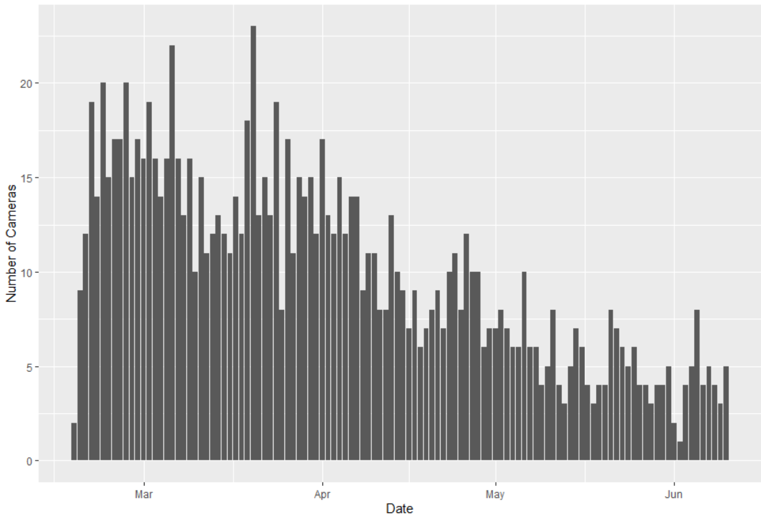
Appendix A: Camera Activity



a)



b)

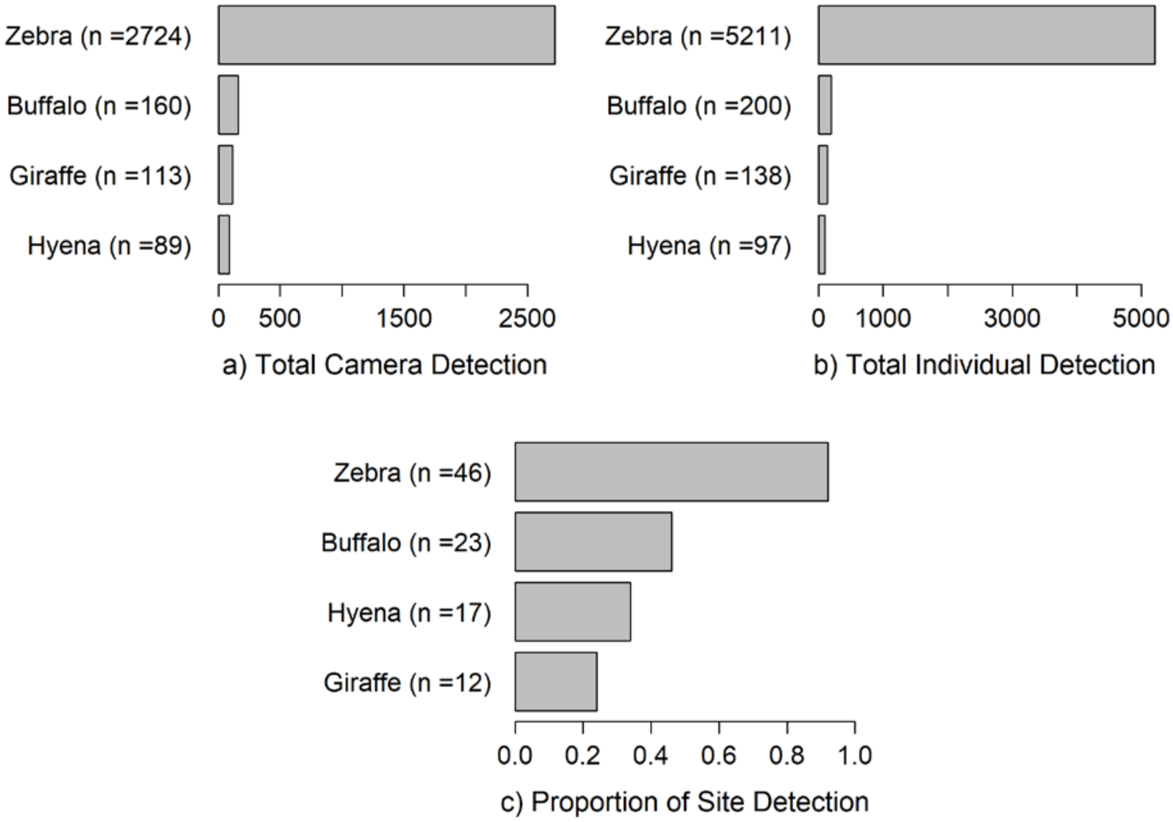


c)

Summary statistics over time for the (a) total number of captures, (b) Number of Individuals and (c) Number of cameras with captures.

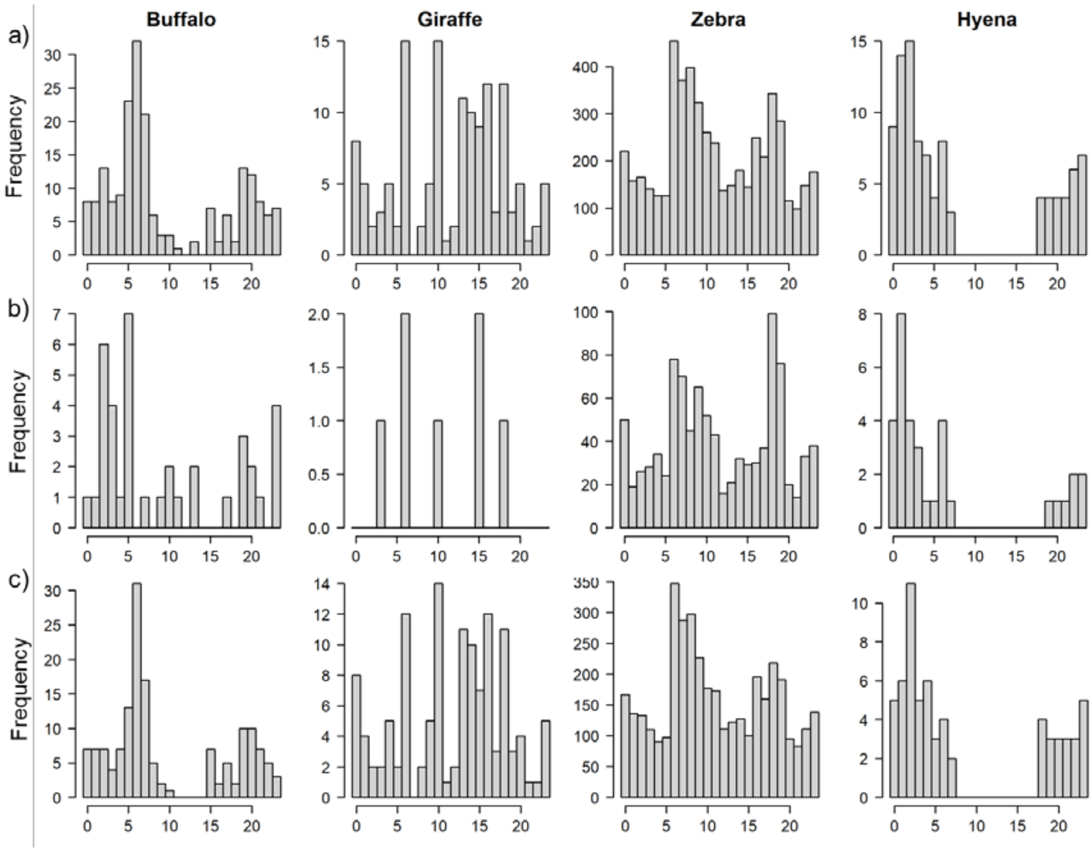
Appendix B: Camera and species detection patterns over time

Across all the study area the total number of camera detections (i.e. one or more individuals identified in a single camera image) was 3086 and a total of 5646 individuals were detected. Zebra were detected in the majority of sites (n=46) while Giraffe were detected in the least number of sites (n=12). In terms of total number of individuals, 5211 Zebra were detected versus 97 Hyena individuals.



The 15-minute detection dataset was processed for (a) Total camera detection, (b) Total individuals detected and (c) Proportion of sites detected.

Appendix C: Daily patterns



Number of individuals of each species detected at the 15-minute interval during the (a) full deployment period, (b) the dry month of February and (c) wet months from March to May. The x-axis indicates the hour, where 0 is midnight.

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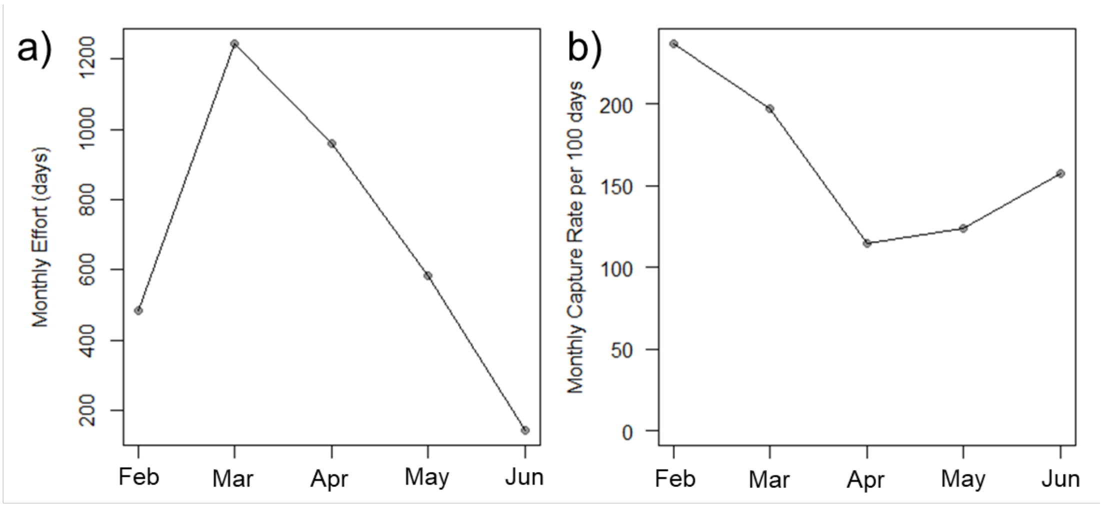
Appendix D: Capture rate over time for all species

The 15-minute individual detections capture details for each of the 50 cameras deployed, number of individuals captured, species presence, number of capture and capture rate per 100 days. Cameras V13-S and V23-M that is highlighted in red went missing less than a week after deployment.

Camera	Species Presence					Number of Individuals					Capture Rate				
	Buffalo	Giraffe	Zebra	Hyena	Total No. of Species per Camera	Buffalo	Giraffe	Zebra	Hyena	Total	Buffalo	Giraffe	Zebra	Hyena	Overall Capture Rate
V01-S	1	0	1	0	2	4	0	303	0	307	9	0	659	0	667
V02-S	1	0	1	1	3	15	0	422	3	440	15	0	418	3	436
V03-S	0	0	1	1	2	0	0	180	6	186	0	0	254	8	262
V04-S	1	0	1	0	2	2	0	151	0	153	4	0	321	0	326
V05-S	0	0	1	0	1	0	0	93	0	93	0	0	291	0	291
V06-S	0	0	1	0	1	0	0	225	0	225	0	0	346	0	346
V07-S	0	0	1	1	2	0	0	95	2	97	0	0	792	17	808
V08-S	1	0	1	1	3	38	0	433	44	515	36	0	405	41	481
V09-S	1	0	1	1	3	9	0	112	5	126	10	0	129	6	145
V10-S	1	0	1	1	3	25	0	301	13	339	23	0	274	12	308
V11-S	0	0	1	0	1	0	0	14	0	14	0	0	175	0	175
V12-S	1	0	1	0	2	5	0	24	0	29	33	0	160	0	193
V13-S	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
V14-S	1	0	1	0	2	22	0	137	0	159	19	0	120	0	139
V15-M	1	1	0	0	2	1	14	0	0	15	1	15	0	0	16
V16-M	0	0	1	0	1	0	0	1	0	1	0	0	9	0	9
V17-M	0	1	1	0	2	0	4	8	0	12	0	18	36	0	55
V18-M	0	1	1	0	2	0	25	18	0	43	0	27	19	0	46
V19-M	1	1	1	1	4	2	6	30	1	39	5	15	77	3	100
V20-M	1	1	1	0	3	2	15	49	0	66	2	17	56	0	75
V21-M	0	1	1	0	2	0	8	51	0	59	0	11	71	0	82
V22-M	0	1	1	0	2	0	38	1	0	39	0	45	1	0	46
V23-M	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
V24-M	0	1	0	0	1	0	20	0	0	20	0	36	0	0	36
V25-M	0	1	1	0	2	0	2	34	0	36	0	4	69	0	73
V26-M	0	0	1	0	1	0	0	137	0	137	0	0	159	0	159
V27-M	0	0	1	1	2	0	0	193	1	194	0	0	233	1	234
V28-M	0	0	1	0	1	0	0	46	0	46	0	0	139	0	139
V29-M	0	0	1	0	1	0	0	236	0	236	0	0	262	0	262
V30-M	0	0	1	0	1	0	0	89	0	89	0	0	113	0	113
V31-M	1	0	1	1	3	2	0	51	2	55	2	0	56	2	60
V32-M	1	0	1	0	2	15	0	38	0	53	18	0	45	0	62
V33-M	1	1	1	1	4	20	1	163	1	185	23	1	187	1	213
V34-M	1	0	1	0	2	10	0	106	0	116	9	0	99	0	108
V35-M	1	0	1	1	3	1	0	128	6	135	1	0	117	6	124
V36-M	0	0	1	0	1	0	0	61	0	61	0	0	111	0	111
V37-M	1	1	1	1	4	1	1	44	1	47	2	2	107	2	115
V38-M	1	0	1	0	2	3	0	30	0	33	3	0	27	0	30
V39-M	0	0	1	0	1	0	0	2	0	2	0	0	3	0	3
V40-M	1	0	1	1	3	2	0	474	1	477	6	0	1394	3	1403
V41-M	1	0	1	1	3	17	0	117	1	135	15	0	104	1	121
V42-M	0	0	1	0	1	0	0	9	0	9	0	0	19	0	19
V43-M	1	0	1	0	2	2	0	31	0	33	2	0	28	0	30
V44-M	0	0	1	0	1	0	0	13	0	13	0	0	19	0	19
V45-M	0	0	1	0	1	0	0	55	0	55	0	0	52	0	52
V46-M	0	0	1	1	2	0	0	1	8	9	0	0	1	8	9
V47-M	0	0	1	0	1	0	0	73	0	73	0	0	406	0	406
V48-M	1	1	1	1	4	1	4	1	1	7	2	8	2	2	14
V49-M	0	0	1	0	1	0	0	1	0	1	0	0	1	0	1
V50-S	1	0	1	1	3	1	0	430	1	432	1	0	384	1	386
Average Capture Rates											5	4	182	2	194
Total Individuals and Capture Rates						200	138	5211	97	**5646**	6	4	153	3	165
						5646					165				

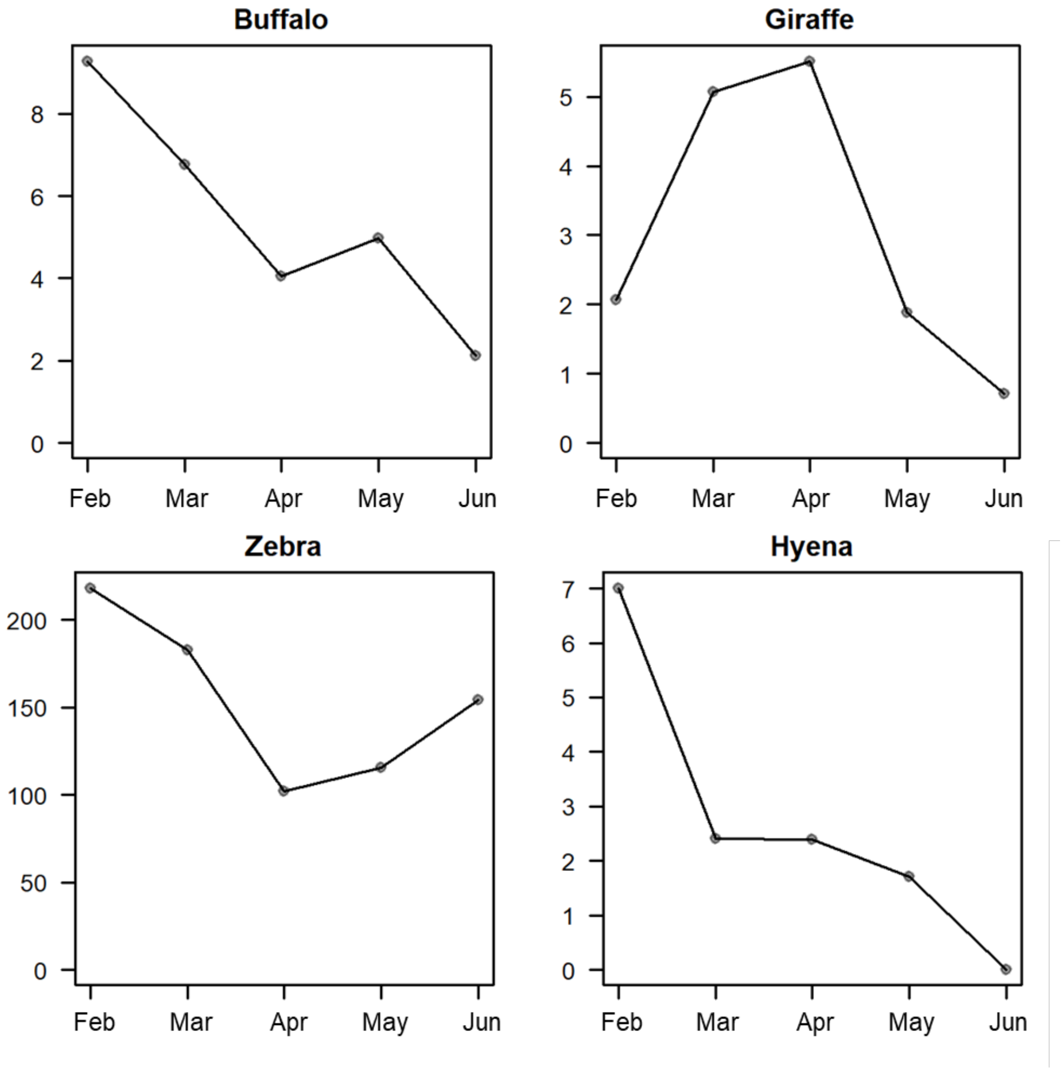
Draft Nairobi-Nakuru-Mau Summit highway wildlife connectivity assessment: camera trap study

Appendix E: Capture rate over time for all species



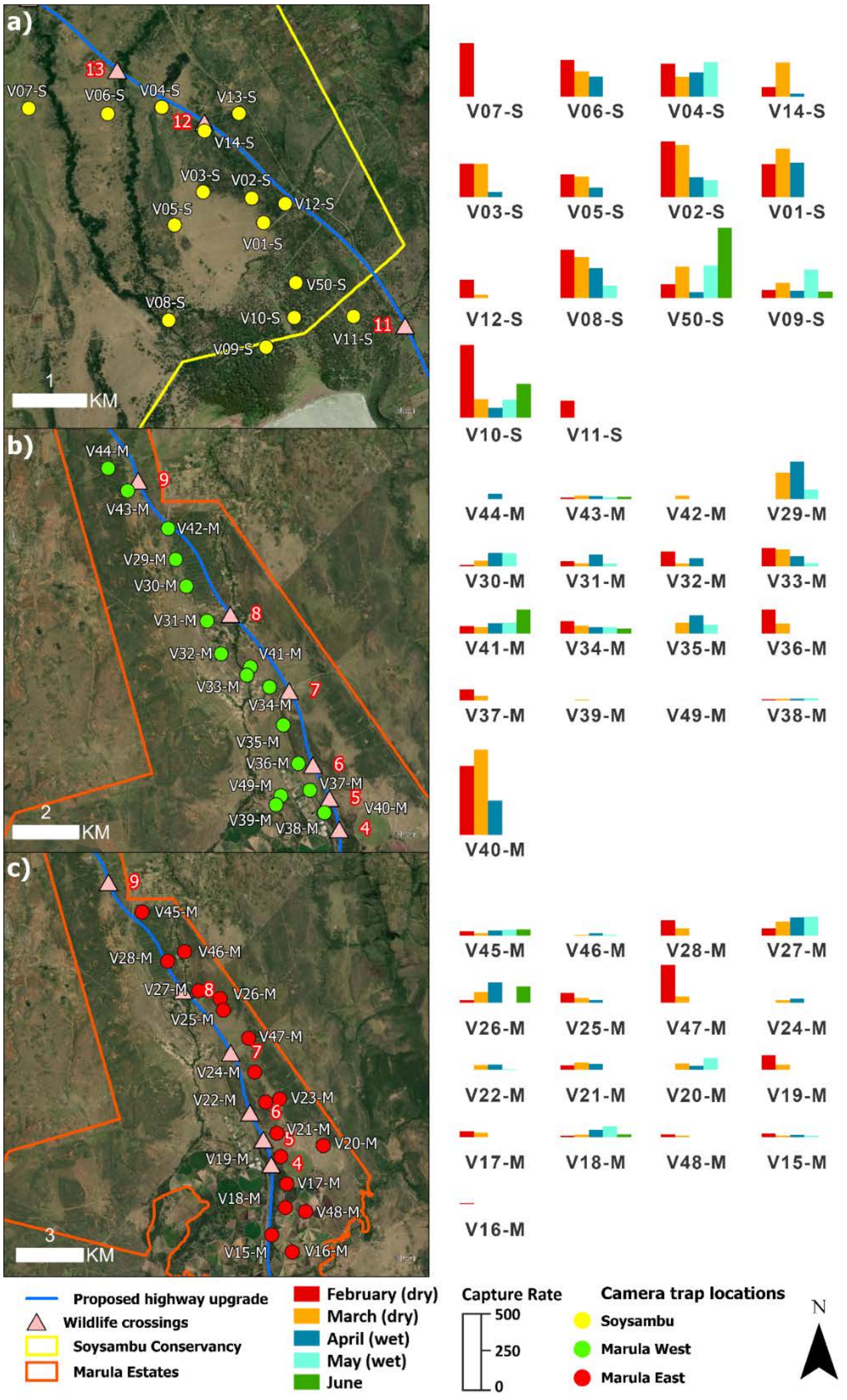
The (a) Monthly effort (number of camera deployment dates) and (b) capture rate per 100 days over time from the 15-minute detection dataset.

Appendix F: Capture rate per species

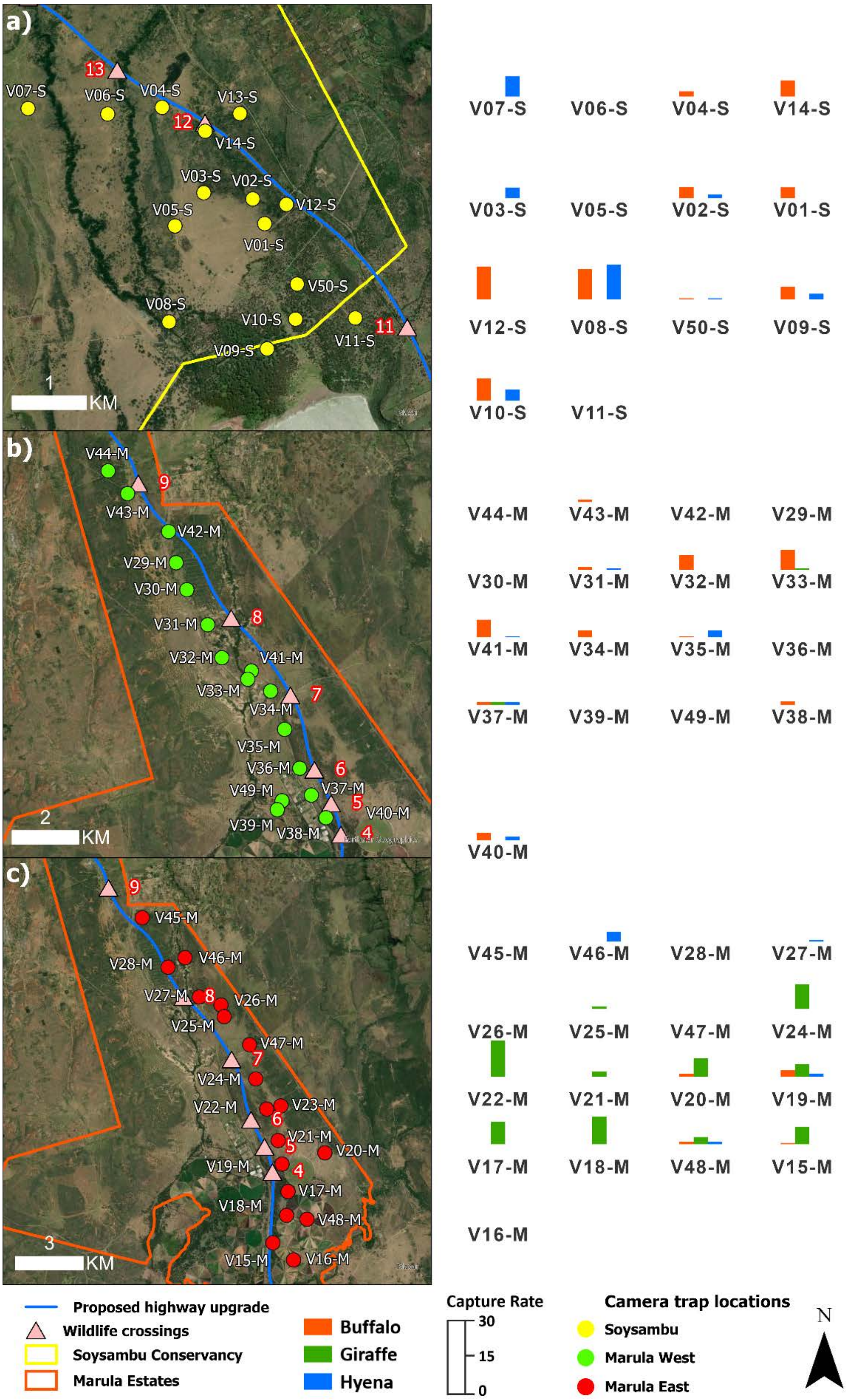


Capture rate per 100 days over time of all four species from the 15-minute detection dataset.

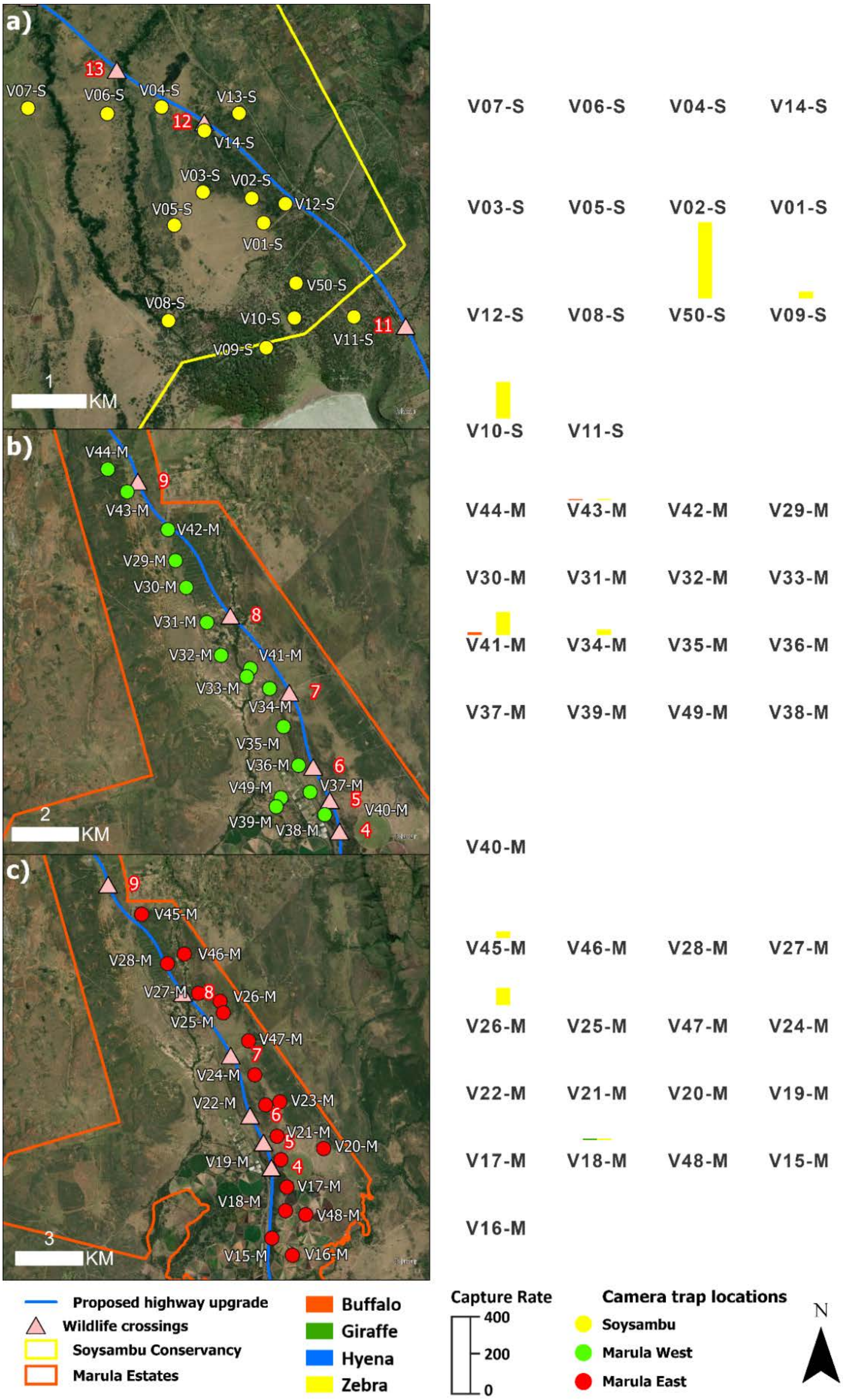
Appendix G: Spatial Assessment



Capture rate per 100 days for each month for each camera in the (a) Soysambu, (b) Marula West and (c) Marula East.

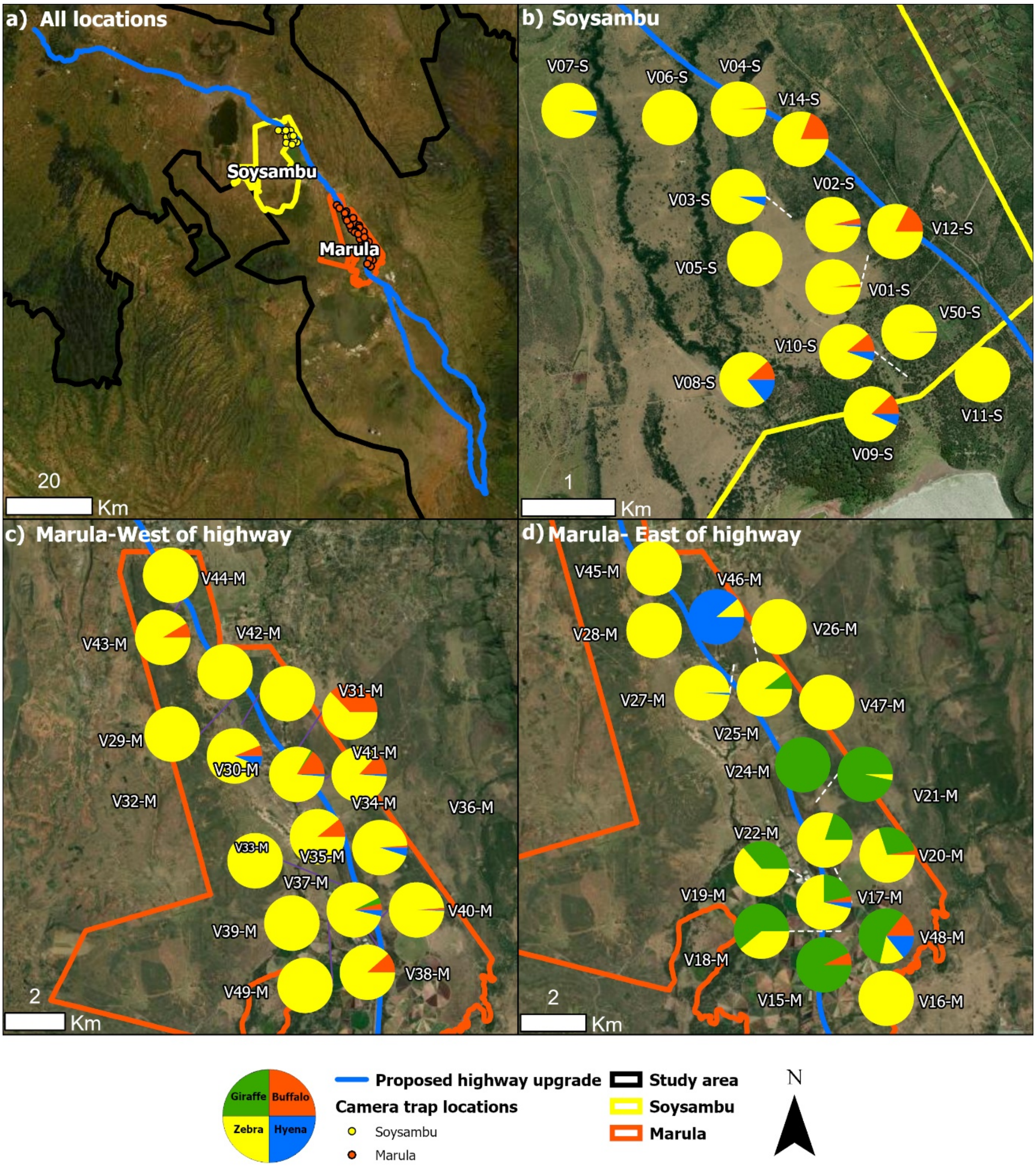


Capture rate per 100 days for the whole camera deployment period for each camera without the Zebra included in (a) Soysambu, (b) Marula West and (c) Marula East.

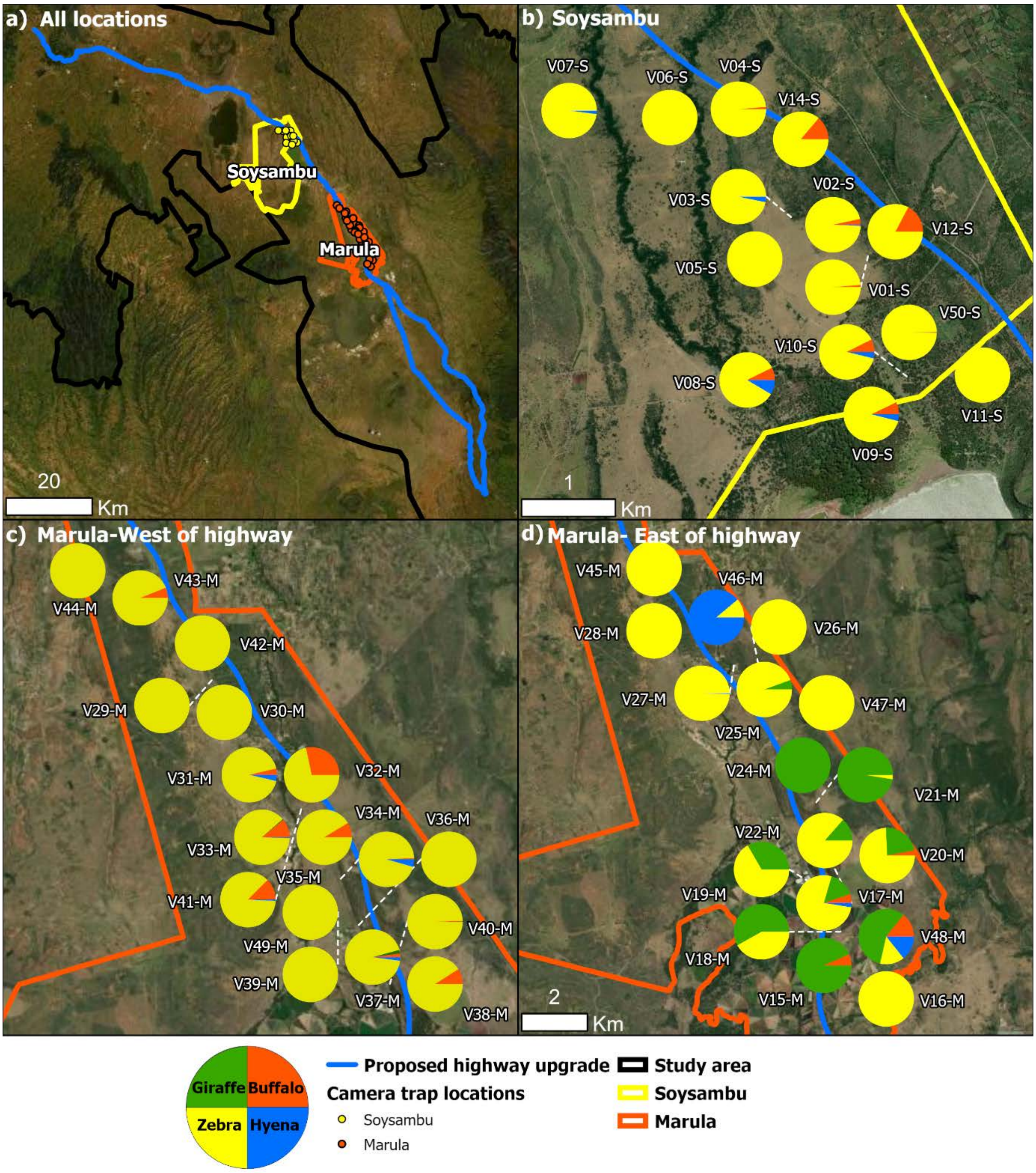


Capture rate per 100 days for June only per species for each camera in the (a) Soysambu, (b) Marula West and (c) Marula East.

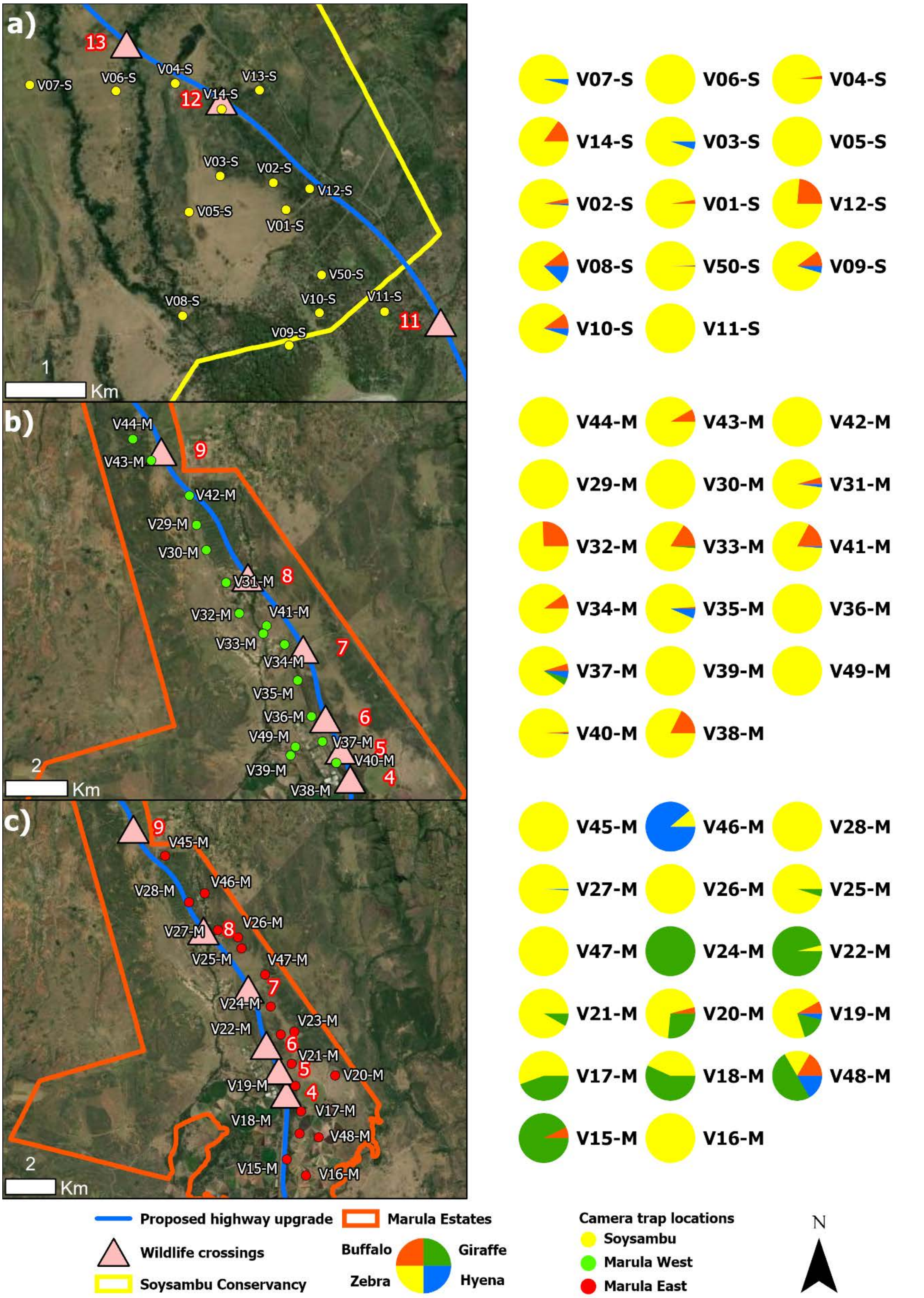
Appendix H: Spatial Assessment Alternative representations



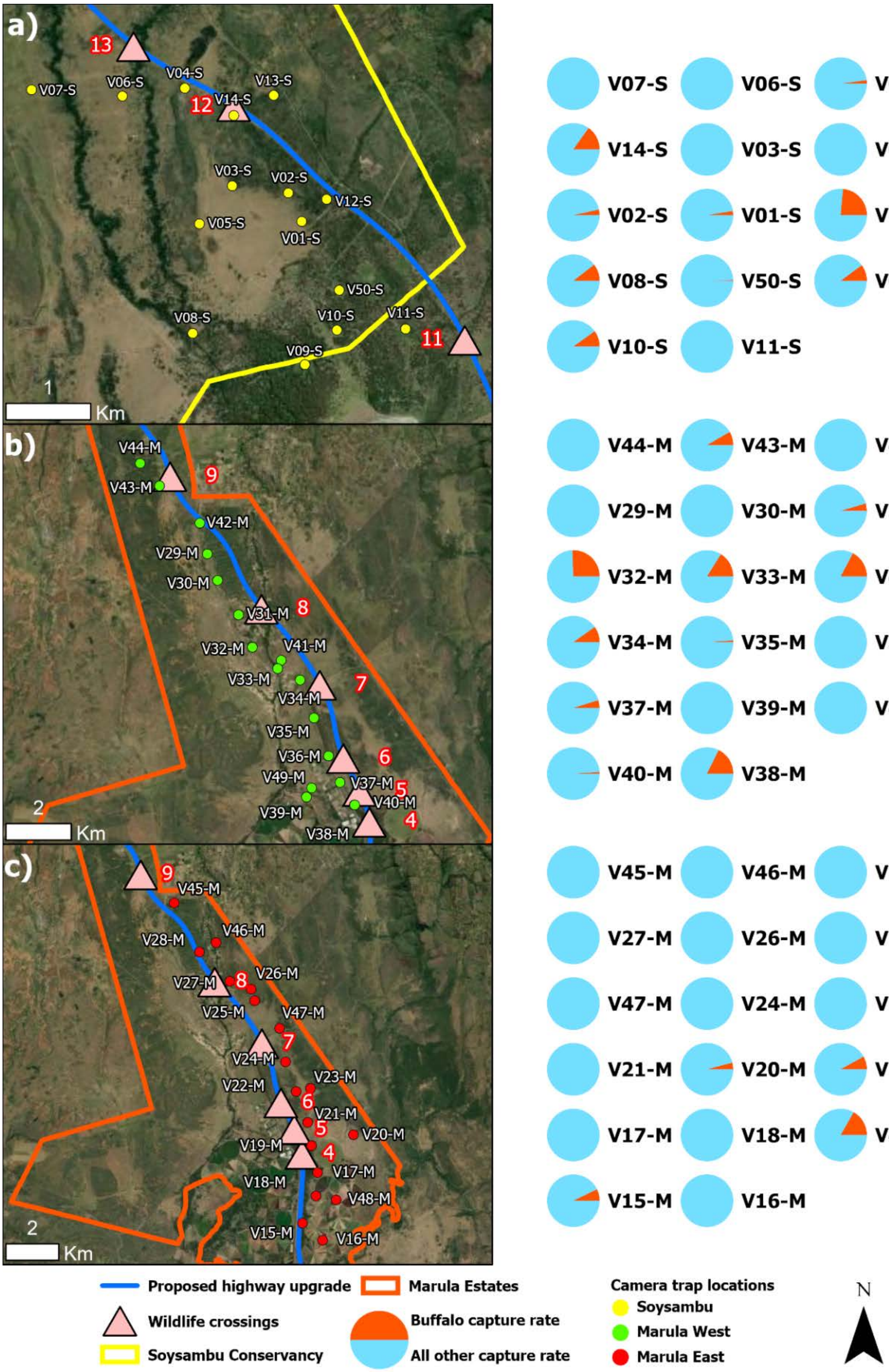
Proportion of individuals per species based on the 30-minute individual detections dataset.



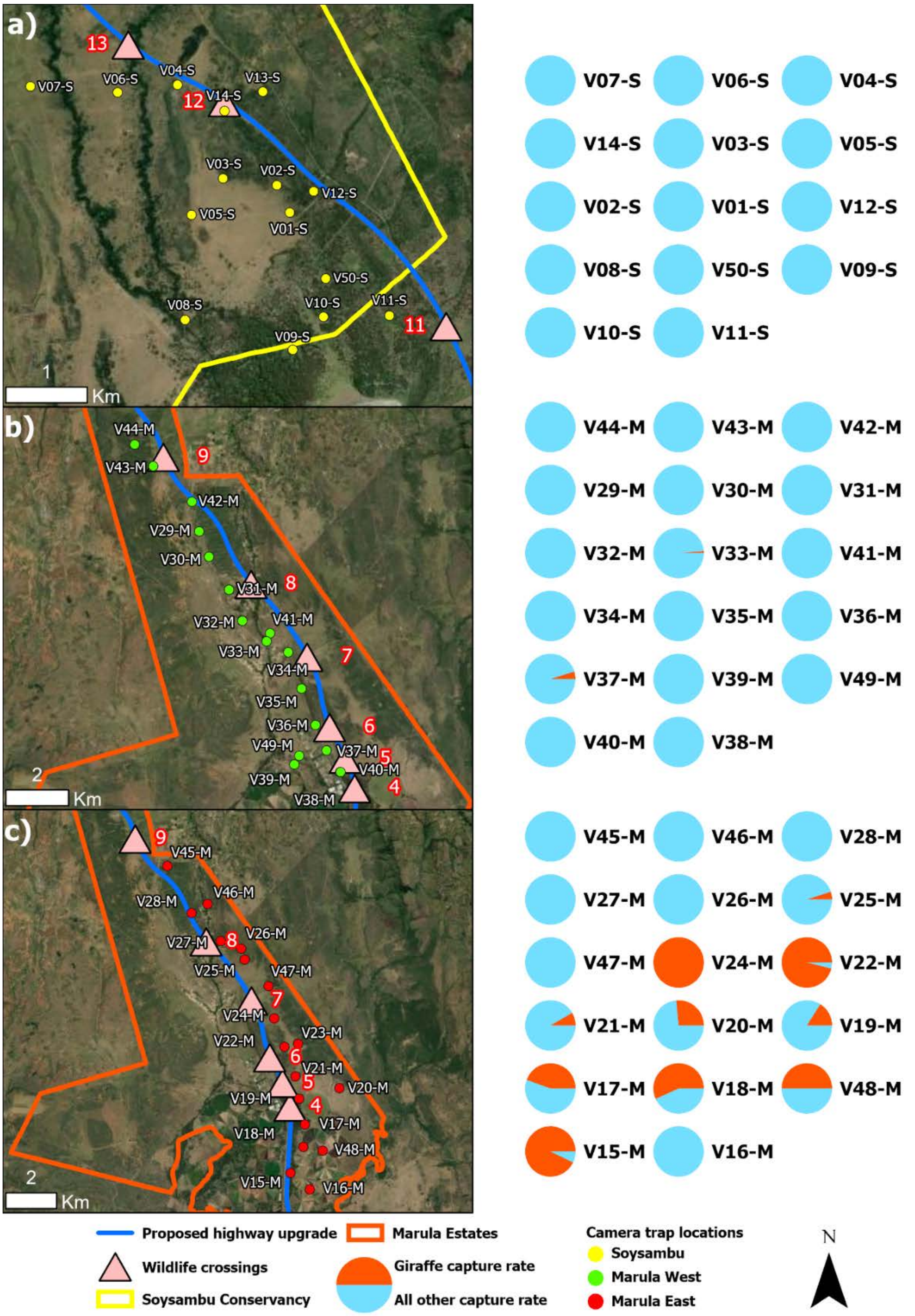
Proportion of individuals per species per camera based on the 30-minute individual detections dataset.



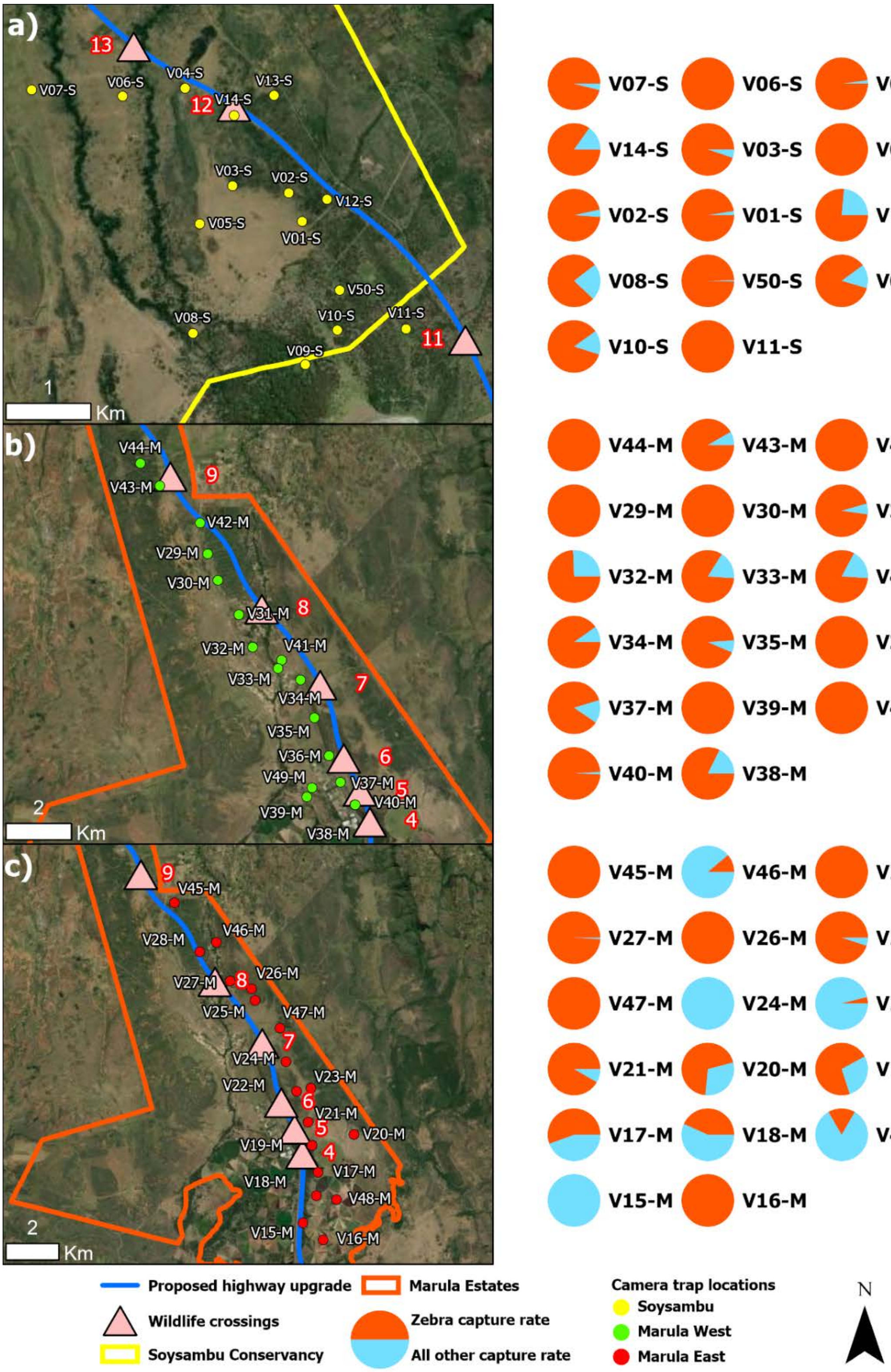
Capture rate per 100 days for each species per camera based on the 30-minute individual detections dataset. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East.



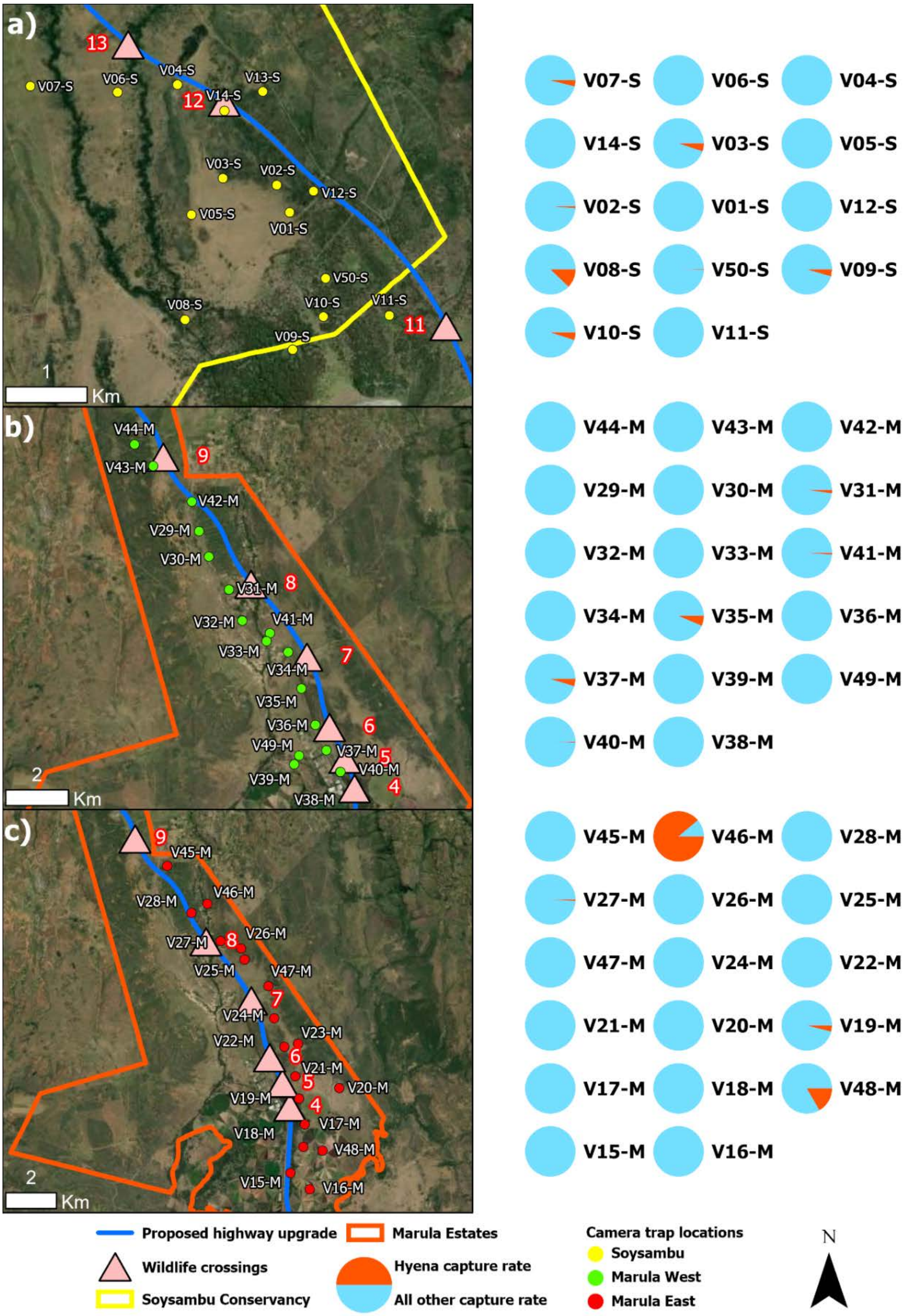
Comparison of Buffalo capture rates against the three other species per camera based on the 30-minute individual detections dataset. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East.



Comparison of Giraffe capture rates against the three other species per camera based on the 30-minute individual detections dataset. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East.



Comparison of Zebra capture rates against the three other species per camera based on the 30-minute individual detections dataset. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East.

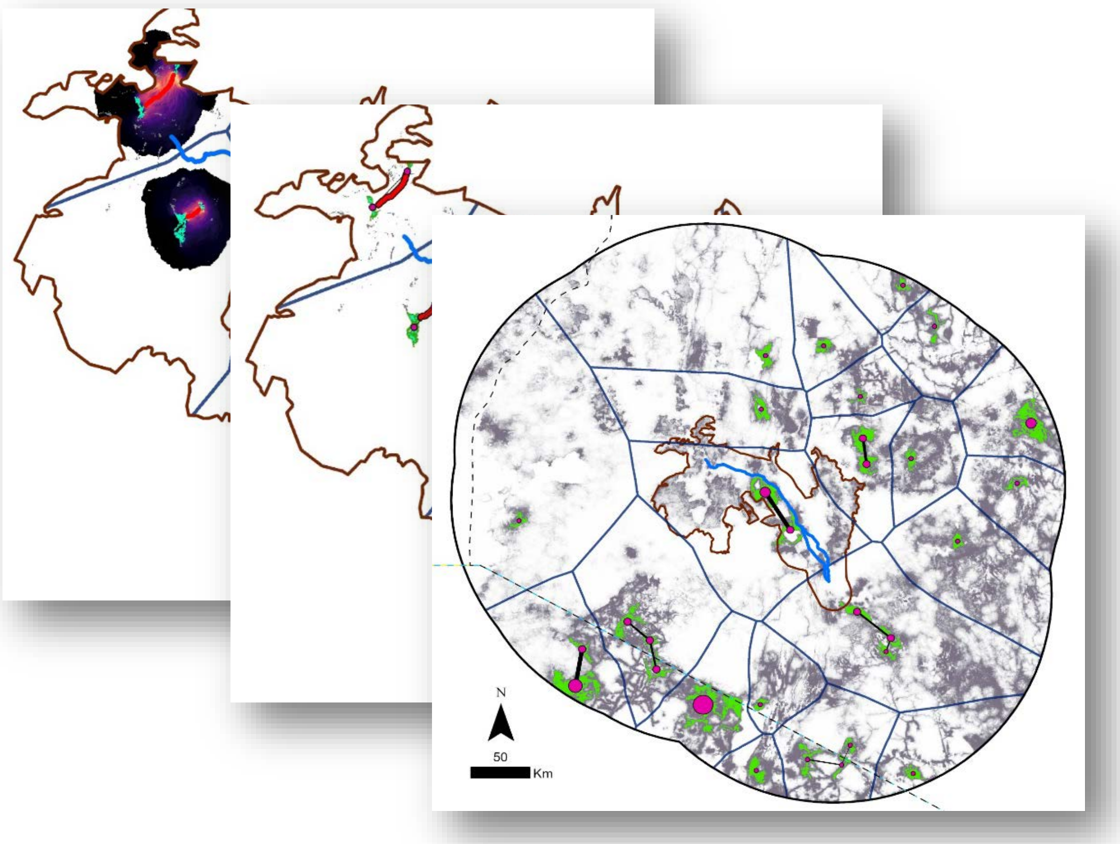


Comparison of Hyena capture rates against the three other species per camera based on the 30-minute individual detections dataset. Figures have been divided based on the camera trap location in the (a) Soysambu, (b) Marula West and (c) Marula East.

APPENDIX

6-20 *HABITAT SUITABILITY AND ECOLOGICAL CONNECTIVITY MODELLING*

Nairobi-Nakuru-Mau Summit highway wildlife connectivity assessment: habitat suitability and ecological connectivity modelling



Dr Alex M. Lechner, Darrel Tiang and Michelle Ang

31 July 2021

Nairobi-Nakuru-Mau Summit highway wildlife connectivity assessment: habitat suitability and ecological connectivity modelling

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Contents

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Glossary

Below is a list of commonly used modelling terms in the report. The terms have been defined from the perspective of this report which in some cases may differ slightly from there general usage.

Term	Definition
Circuit theory	Application of electrical circuit theory to landscape connectivity, where the landscape is considered to be synonymous with an electrical circuit and resistance within a landscape is characterised based on the assumption that current flow corresponds to individual movement probabilities across every grid cell in a raster (see McRae et al 2008). Measured with current density, where high values indicate higher probabilities of an individual randomly found dispersing at a pixel.
Circuitscape	Connectivity modelling software that uses circuit theory (see McRae et al 2008).
Component	A group of nodes or patches of habitat for a particular species or group of species that are linked to each other but isolated from other components.
Connectivity	The degree to which the landscape facilitates or impedes the movement of individuals among habitat patches. Maximising connectivity is often an objective of conservation planning.
Connectivity model	A modelling method for assessing dispersal or movement.
Cumulative cost distance	The cumulative cost distance describes the accumulated travel cost from one location to another based on the resistance surface rather than actual distance.
Current density	This specifically refers to Circuitscape maps outputs where warmer colours refer to areas with higher current density hence higher chance of movement.
Dispersal-cost	A value assigned to each land cover type in a landscape that reflects the ecological costs for individuals to move through it.
Delta Integral Index of Connectivity (dIIC)	A patchscale graph metric which describes the importance of a patch or linkage for connecting habitat in the landscape. The dIIC metric is defined as the relative change in IIC associated with the removal of a patch or linkage. Higher values indicate that a patch or linkage is more important for connecting the landscape.
Graphab	A software for modelling ecological networks using landscape graphs and least-cost paths (see Foltête et al. 2012)
Graph	A set of linked nodes/patches. Applied to landscape ecology a graph is a set of patches within a landscape linked by movement pathways.
Graph theory	The graph theoretic perspective applied to landscape ecology represents landscapes as a graph; whereby the landscapes are composed of a series of nodes (patches). Graph theory uses mathematical structures to describe pairwise relations between nodes.
Graph metrics	Metrics derived using graph theory to describe connectivity at the landscape scale or patch scale.
Habitat Suitability Index (HSI)	The outputs from the MaxEnt modelling are raster surfaces describing by a habitat suitability index (HSI) with values ranging from 0 to 1. Where 0 represent unsuitable areas and 1 represent very suitability areas.
Integral Index of Connectivity (IIC)	A landscape-scale metric that describes how connected habitat is within a landscape. The IIC metric is defined as the probability that two points randomly placed within a landscape fall into habitat areas that can be reached. Values for this metric increase with greater connectivity from zero to one. Higher values indicate that a landscape is highly connected.
Interpatch-crossing distance threshold	The maximum distance that individuals would move between patches provided there is some kind of structural connectivity element such as stepping-stones (for example, scattered trees) or corridors.

Landscape-scale graph metric	A graph metric that describes how well a whole landscape is connected.
Least-cost path	The shortest pathway between two patches as a function of land cover resistance. i.e. the optimal pathway between two patches for an individual to move.
Least-cost corridor	An alternative to calculating a least-cost path is calculating the least-cost corridor. A least-cost corridor is defined as a corridor between two patches where its width is limited by the cost-weighted distance threshold defined by the resistance surface and interpatch dispersal distance threshold.
Link/Linkages	A linkage is a pathway between patches of habitat described by a least-cost path.
Linkage Mapper	Connectivity modelling software which combines least-cost corridors with Circuitscape. In this report it is used to characterise pinch-ipoints.
MaxEnt	Species distribution modelling software used to map habitat suitability with presence-only species records and environmental explanatory data (Phillips et al., 2006).
Matrix	Species specific non-habitat areas. Areas between patches which individuals move through. Commonly characterised by anthropogenic land uses such as pasture or residential areas.
Network/Graph	A graph theory term describing a collection of nodes connected by links. In landscape ecology, nodes and links represent patches and pathways within a landscape.
Node	An element of a network/graph that is represented by patches in landscape ecology.
Patch	A relatively homogeneous area, often habitat, which differs from its surroundings. In this study, patches are defined as an area of indigenous vegetation greater than the minimum size for a focal species or scenario being tested. These are represented by nodes in graph theory.
Patch-scale graph metric	A graph metric that describe how important a patch or a link is for connecting the whole landscape.
Pinch-point	Pinch-points (or choke-points) (calculated with Circuitscape) are areas where animal movement is constrained within corridors and represent areas where linkages are most vulnerable to being severed.
Presence-only species record/data	Records for a species available only as presence only. i.e. lack data on where species are not located.
Raster	A rectangular grid of pixels commonly used in a GIS to represent land cover.
Resistance	A value assigned to each land cover type in a landscape that reflects the ecological costs for individuals to move through it. Also, sometimes referred to as dispersal-cost. High resistance means high dispersal costs.

Executive summary

The University of Nottingham Malaysia was commissioned by WSP on behalf of Rift Valley Highways Limited Consortium (RVHL), Government PPP Partners to assess the potential impacts of the proposed upgrade of the Nairobi-Nakuru-Mau Summit highway on ecological connectivity and inform the identification of the optimal locations for the wildlife crossing structures.

This study quantified ecological connectivity for three key conservation target species (i) Giraffe (*Giraffa spp.*), (ii) Plains zebra (*Equus quagga*) and (iii) African Buffalo (*Syncerus caffer*) at two scales:

1. Regional Assessment Area - study area used for the Environmental and Social Impact Assessment (ESIA)
2. Contextual Assessment Area which includes the Regional Assessment Area and the surrounding area within 170 km.

The aim of this project was to assess the impact of the proposed highway upgrade on wildlife connectivity and support the selection of wild crossings via the following five tasks:

1. Apply web-based public participatory mapping and surveys with local experts and stakeholders to identify key conservation species, and obtain feedback on the methods and outputs.
2. Map Contextual Assessment Area species distribution.
3. Map connectivity in the Contextual Assessment Area to characterise the importance of habitat near the highway development for connecting critical sections of the region.
4. Characterise connectivity in the Regional Assessment Area to assess the impacts of the highway on fragmentation.
5. Assess optimal locations for wildlife crossings.

The analysis was conducted using leading practice connectivity modelling methods which included: (i) habitat suitability modelling with presence-only species data using MaxEnt and (ii) ecological connectivity modelling using least-cost path analysis, Circuitscape and graph metrics.

The modelling of the larger Contextual Assessment Area was undertaken to include more ecological data to improve the robustness of the species distribution model, and also to quantify the contribution of the habitat within the Regional Assessment Area to connections from and into the Contextual Assessment Area.

The modelling of the Contextual Assessment Area suggested that the Regional Assessment Area is isolated ecologically from the surrounding areas. The habitat suitability modelling for the Regional Assessment Area identified two large, connected agglomerations of protected areas and habitat. The agglomeration in the north included Lake Nakuru National Park, and Soysambu Conservancy. The agglomeration in the south included Marula Estate, and other private estates and wildlife conservancies around Lake Naivasha, together with formal protected areas such as Hell's Gate and Mount Longonot National Parks lake. Large areas of habitat, least-cost paths and high movement probability were more commonly found to the west of the highway than to the east.

The greatest area of habitat intersected by the road was in the southern agglomeration around the Marula Estate. According to the modelling, the wildlife crossings in this area are likely to provide the greatest benefit to ecological connectivity and persistence for the target species and support movement between core habitat i.e. large areas of highly suitable habitat. In addition, all of the wildlife crossings are likely to contribute to the persistence of the target species, and many other species that would also use these structures. This wildlife crossing assessment provided a quantitative assessment of the importance of each of the 13 potential wildlife crossing points (identified in a previous study by local experts). The final selection and design of these crossings, and indeed potentially the inclusion of other locations, should be informed field data, road design and expert local knowledge.

The modelling of the habitat, connectivity patterns and wildlife crossing assessment for the three conservation targets characterised a complex range of ecological patterns which can be used to guide decision support. The habitat suitability and connectivity mapping successfully produced robust outputs which also concurred with the expert feedback and other mapping products in the region.

The application of connectivity modelling approaches to the Nairobi-Nakuru-Mau Summit highway development provides a transparent and quantitative approach to assessing impacts and evaluating the likely importance of wildlife crossings. However, it is important to recognise a range of sources of uncertainty, in particular, a lack of occurrence data and key environmental explanatory spatial data (i.e. fence lines adjacent to the road as well as fence-type) and the positional errors in the protected area spatial data. The web-based expert survey was able to address these issues to some degree, however, the level of engagement with local experts and stakeholders was not high.

The modelling presented in this study represents a leading practice approach to undertaking an ESIA with publicly available data, within the time-limitations and budget constraints of this project. The results need to be considered as just one input in the decision-making process along with other impacts unmeasured by the modelling when deciding on the final choice of wildlife crossing. It is recommended that ongoing monitoring of the wildlife crossings and adaptive management be undertaken as a precaution.

1.0 Introduction

1.1. Overview

The University of Nottingham Malaysia was commissioned by WSP on behalf of Rift Valley Highways Limited Consortium (RVHL), Government PPP Partners to assess the potential impacts of the proposed upgrade of the Nairobi-Nakuru-Mau Summit highway on ecological connectivity and inform the identification of the optimal locations for the wildlife crossing structures.

This study focused on the ecological connectivity for three key conservation target species at two scales: Giraffe (Giraffa spp.), Plains zebra (Equus quagga) and African buffalo (Syncerus caffer). These species were chosen because they are endangered and thus a conservation priority, and because many other species of wildlife are likely to be accommodated if the needs of these target species are met.

1.2. Scope

The aim of this project is to assess the impact of proposed highway upgrade on wildlife connectivity and support the selection of wild crossings, in order to reduce the impacts of fragmentation on biodiversity and prevent collisions.

The study involved the following objectives:

Identify priorities for existing habitat

- Characterise the distribution of the conservation target species in terms of core habitat locations, habitat suitability and areas of wildlife movement.

Assess likely effects

- Assess the likely direct and indirect effects of the proposed highway upgrade on connectivity of the conservation targets species.

Identify optimal location of mitigation measures

- Inform the final selection, placement/position and design of wildlife crossings (underpasses and overpasses).

The analysis was conducted using (i) habitat suitability modelling with presence-only species data and ecological connectivity modelling using least-cost path analysis, Circuitscape and graph metrics, to (ii) characterise how the proposed Nairobi-Nakuru-Mau Summit highway upgrade will fragment the landscape and affect wildlife movement, and to (ii) identify optimal location of mitigation measures to reduce these negative impacts. In conjunction with the spatial analysis, web-based mapping and expert surveys was carried out to identify key conservation species and obtain feedback on the methods and outputs, in particular for parameterising the model.

The spatial analysis was conducted at two scales:

1. Regional Assessment Area (RAA); defined and used for the purpose of the ESIA.

2. Contextual Assessment Area (CAA) which includes the RAA and the surrounding area within 170 km. Two key reasons for modelling the larger study area was so that (i) the larger area included more ecological data which could be used to develop a more robust species distribution model, and also (ii) to quantify the contribution of the habitat within the regional assessment area to connectivity across the surrounding regions (i.e. to north-south connectivity within Kenya) and how connectivity may affect habitat at the regional-scale.

To address the study objectives described above the following tasks were performed followed:

Task 1: Apply web-based public participatory mapping and surveys with experts to confirm the key conservation target species modelled, and obtain feedback on the methods and outputs, from local experts and stakeholders.

Task 2: Map species distribution in the CAA for the three target species with presence-only records and environmental explanatory variables.

Task 3: Map connectivity in the CAA to characterise the importance of habitat near the highway development for connecting the region.

Task 4: Characterise connectivity in the RAA to assess impacts of the highway on fragmentation

Task 5: Identify optimal areas for wildlife crossings in the RAA

This is report 1 of a two-part assessment. In the second report we analyse camera trap data located in the RAA.

1.3. Background

1.3.1. Fragmentation and road impacts

Roads have a variety of negative consequences on animal populations, ranging from direct effects such as habitat destruction to roads obstructing individual movement (Barrientos et al., 2019; Benítez-López et al., 2010; Hanski, 1994; van der Ree et al., 2015). Habitat loss results in the restriction of species mobility from contiguous ecosystems fragmented into patches often due to land use change (Brook et al., 2008; Debuse et al., 2007; Fischer and Lindenmayer, 2007). A loss of connectivity reduces genetic viability and the ability of individuals to recolonise, and over time, as populations decrease they are at risk of localised extinction, which can ultimately leads to species extinction. Fragmentation is caused by a variety of land use change drivers such as agriculture and urbanisation, with road construction being one of the most significant contributors to fragmentation and biodiversity loss globally (Laurance, 2015; Laurance et al., 2014; van der Ree et al., 2015).

Habitat loss from clearance for roads cause contiguous areas to be subdivided into smaller habitat patches. These patches may no longer be able to support a self-sustaining sub-population of individuals, unless they are sustained by immigration from neighbouring sub-populations after patch size falls below a minimum feasible area. In addition, a range of interacting biotic and abiotic factors often causes a reduction in habitat quality around highways such as through changes in microclimate and the encouragement of invasive species; these effects are known as edge effects (Forman and Godron, 1986). Due to higher road mortality for individuals crossing roads and road avoidance behaviour associated with traffic and lights, roads can be barriers or filters to wildlife movement. While mortality from vehicle collision can impact on the size of wildlife populations (Barrientos et al., 2019). The effects of fragmentation will vary over time, with habitat loss noticeable nearly immediately, then decreasing habitat quality and traffic mortality taking longer, and finally a decrease in connectivity taking even longer (Rauschmayer and Risse, 2005).

1.3.2. Connectivity modelling methods

Connectivity modelling accounts for the location, total area and connections among patches and can be used to assess the potential implications of proposed road developments and inform the design process (Clauzel et al., 2015; Lechner et al., 2015, 2017). Existing landscape connectivity modelling tools, including least-cost path analysis, Circuit theory, and graph theory (Foltête et al., 2021, 2012; McRae et al., 2008; McRae and Kavanagh, 2011; Rayfield et al., 2011; Torre et al., 2019), provide a sophisticated and diverse toolkit for investigating various aspects of connectivity (Figure 1). These approaches classify non-habitat/matrix based on a species' dispersal costs, which reflects the mortality risk, behavioural changes and metabolic expense of travelling across the unsuitable habitat (i.e. the matrix). Land cover features are often used to indicate dispersal costs and are described by species-specific dispersal cost probabilities. These dispersal costs are then used to model least-cost paths, which are the optimal pathways used by a species to move between two patches of habitat. The significance of patches and pathways for connecting patches in a landscape can then be quantified using graph theoretic mathematical methodologies. Circuit theory, on the other hand, represents an alternative approach to modelling dispersal, in which the landscape is equated to an electrical circuit and resistance within the landscape is based on the assumption that current flow corresponds to individual movement probabilities across every grid cell in a raster (McRae et al., 2008).

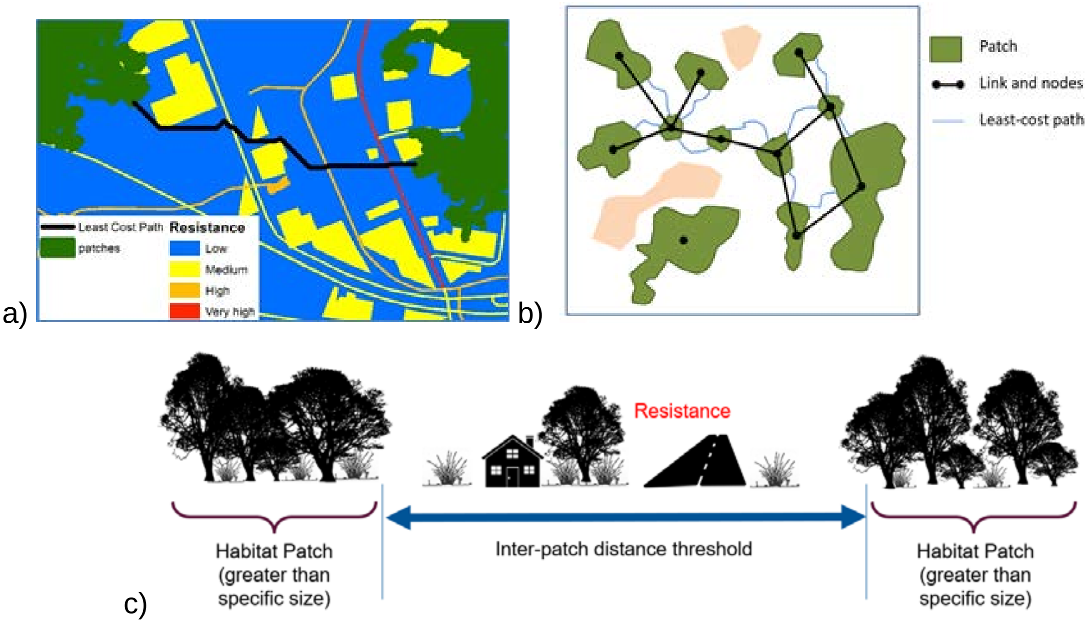

Figure 1: a) A least cost-path represents the optimal path between two patches which avoids hostile species-specific land cover within the matrix (i.e. non-habitat). This example shows how the least-cost path (black line) avoids location of higher resistance (yellow shading) when moving between two patches (green shading). b) In order to apply a graph theoretic approach to a landscape with multiple patches of habitat, patches and least-cost paths are summarized as a set of nodes (black dots) and linkages (black lines). Graph theory can then be used to mathematically determine the relative importance of each patch and linkage for connecting a landscape. c) Conceptual model of connectivity, whereby habitat patches are connected if the distance between two patches is less than an interpatch distance threshold and movement is not prevented by the resistance from land cover in the matrix.

1.4. Modelling methods

For this study we combined species distribution modelling and least-cost path analysis, graph theory and circuit theory to assess wildlife and habitat connectivity. This approach was supplemented with expert and stakeholder surveys to parameterise the model inputs and then review and validate the model outputs (described in the next section).

We used the species distribution modelling software MaxEnt (Phillips et al., 2006) which uses the Maximum Entropy modelling algorithm to characterise habitat suitability for our target species. MaxEnt estimates the relationship between presence-only species (occurrence) records and environmental data (explanatory variables/covariates) at the species record locations and using this relationship produces a raster surface describing habitat suitability (Figure 2). Explanatory variables can include vegetation cover, elevation, rainfall etc. MaxEnt is particularly useful for modelling where data is not collected systematically (i.e., in formal biological surveys), where biological survey data has limited coverage and where data is mainly available as presence-only records (i.e. no species absence records, GPS tracking or long-term camera trap records) (Elith et al., 2011). MaxEnt is perhaps the most well-known method for modelling species distributions with presence-only records and the paper by Phillips et al. (2006) which introduces MaxEnt has been cited 13833 times in Google scholar (01/07/2021).

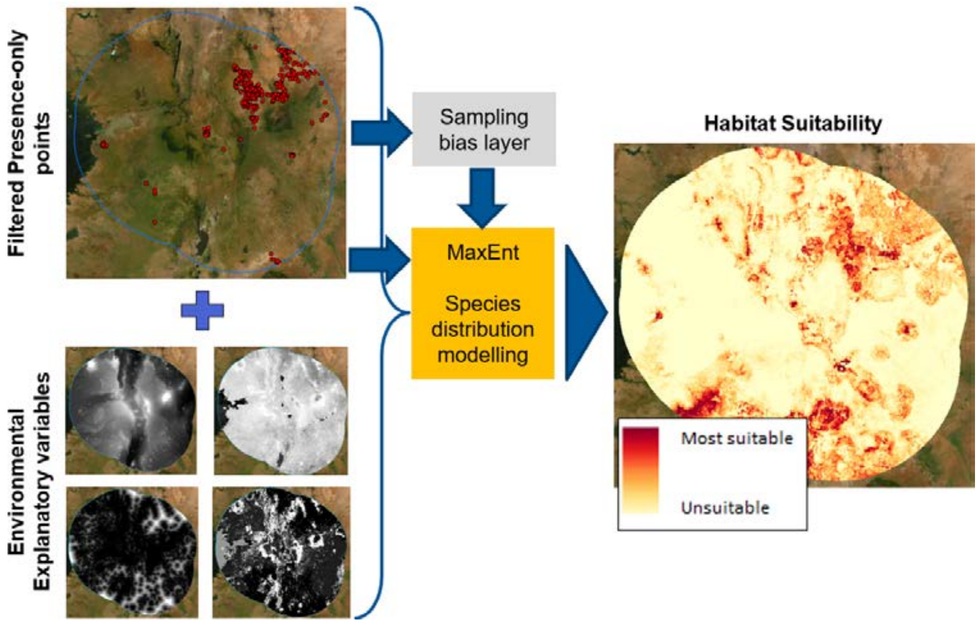

Figure 2: Schematic diagram describing the application of the MaxEnt species distribution modelling for assessing habitat suitability. Presence-only species occurrence points are filtered for accuracy and the relationship with environmental data is quantified in order to map habitat suitability for a particular species. MaxEnt also addresses potential sampling bias associated with the distribution of the presence-only occurrence points.

Habitat suitability surfaces created with species distribution modelling can then be applied to connectivity modelling (Duflot et al., 2018) (Figure 3). This common method for modelling connectivity uses habitat suitability maps, usually derived using MaxEnt, to describe the distribution of patches of habitat and the resistance of the matrix to movement. Connectivity modelling software such as Graphab (Foltête et al., 2021, 2012) and Linkage Mapper (with Circuitscape) are used with these maps as inputs to calculate graph-metrics, least-cost paths and individual movement probabilities within corridors (McRae et al., 2008; McRae and Kavanagh, 2011). Alternative approaches to mapping connectivity including the application of expert-based parameterisation of the habitat and matrix (Lechner et al., 2015, 2017) and utilising radio-tracking movement data along with using step selection functions based on landscape characteristics (Torre et al., 2019).

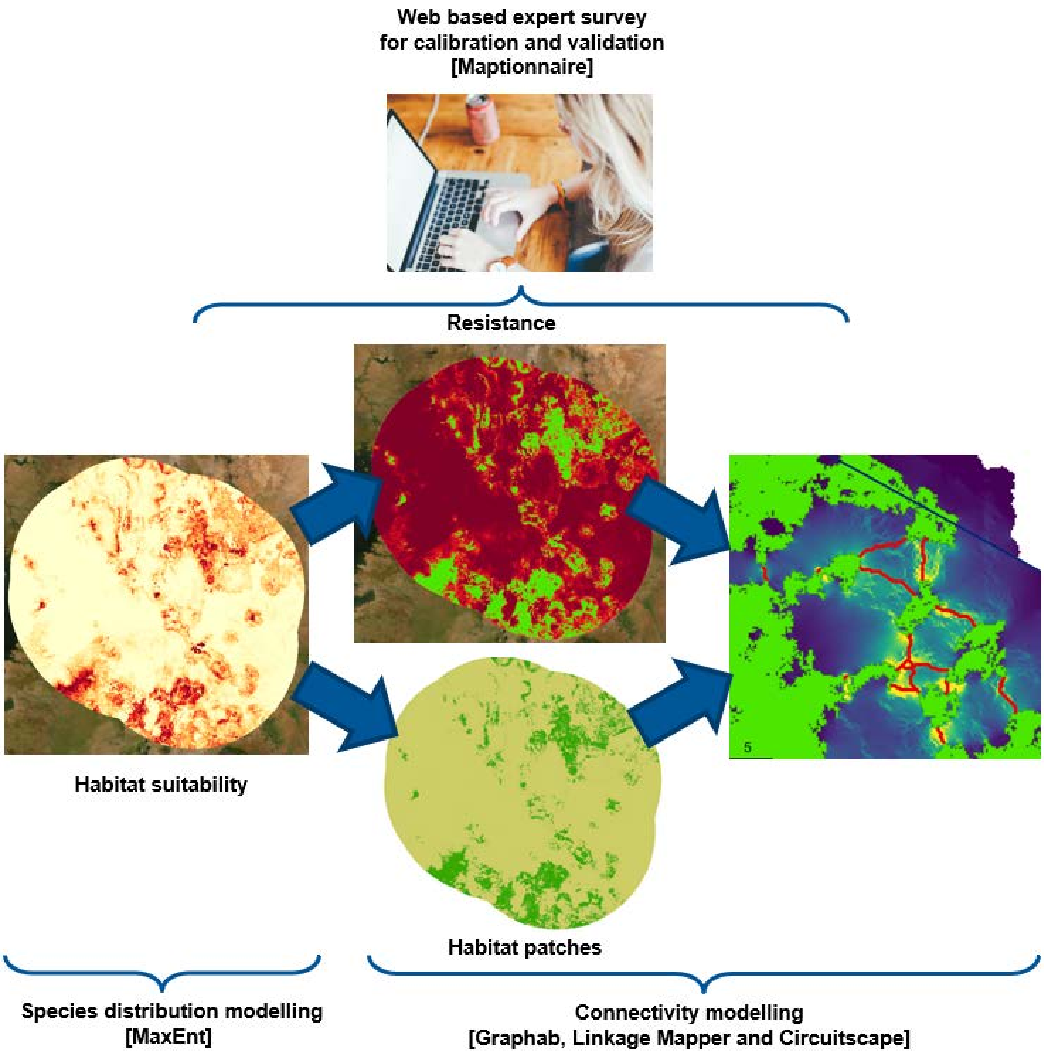

Figure 3: Schematic summarising the two key general modelling methods (species distribution modelling and connectivity modelling) and the application of a web-based expert survey to support the analysis.

1.5. Web-based expert surveys

Web-based participatory mapping Public Participatory Geographic Information System (PPGIS), along with surveys of key expert stakeholders was used to both parameterise the model and validate its outputs. Web-based mapping approaches can be used to integrate the participation of key stakeholder into decision making (Daguil et al., 2015) and can support expert-based feedback on spatially explicit outputs such as remote sensing analyses (Ang et al., 2020). Web-based mapping software such as Maptionnaire (https://maptionnaire.com/) can be used to provide an interactive web-based platform, whereby users can zoom in and out of the maps, turn on and off base layers which include true-colour high resolution imagery and topographical maps, and answer survey questions including mapping responses (i.e. digitising polygons representing missing protected areas). Such an approach is a useful way of interacting with multiple stakeholders without physically being in the same location.

1.6. Leading practice spatial modelling

The combination of methods used in this report were chosen to provide the most robust analyses within the ESIA time period, with the available data, while addressing difficulties with engaging experts due to COVID. Firstly, the data used in the modelling was primarily obtained from publicly available databases and from field surveys within the RAA undertaken for the ESIA by WSP. The use of a large contextual assessment area (CAA) was chosen to maximise the total number of observations included in the analyses to cope with the lack of available data to parameterise the models. While a web-based survey was used in place of holding physical workshops which were impossible due to restrictions and health concerns related to domestic and overseas travel and congregating indoors in meeting rooms.

The approach used in this study represents leading-practice spatial modelling methods used across the world and are most commonly only used for academic studies, as opposed to ESIAs. The methods used is a mathematical, repeatable and transparent approach to characterising landscape connectivity according to our best understanding of the ecology of wildlife movement and dispersal for the study area. However, understanding how wildlife movement operates and how it affects the survival of species is complicated, as it is a property of several factors ranging from the number and size of habitat patches, the spatial distribution of those patches and the permeability (i.e. ability of species to move through a landscape) of the matrix (i.e. the land cover between patches) which are difficult to measure and model. Changing any one of those factors can result in contrasting impacts on a species connectivity. A drawback of our approach is that the methods are spatially complex and involve a series of GIS processing steps. However, sources of uncertainty can be address through expert and stakeholder consultation and scenario analysis using a range of parametrisations.

2.0 Methods

2.1. Methods overview

This study had a number of processing steps which included the application of web-based mapping to the confirmation and parametrisation of conservation targets and modelling ecological impacts, and assessing optimal wildlife crossing locations (Figure 4). The study was conducted at two scales: RAA and CAA. The pixel size for the analysis was 200 m. This was a balance between computational limitations and modelling at a scale relevant to the large-bodied megafauna target species.

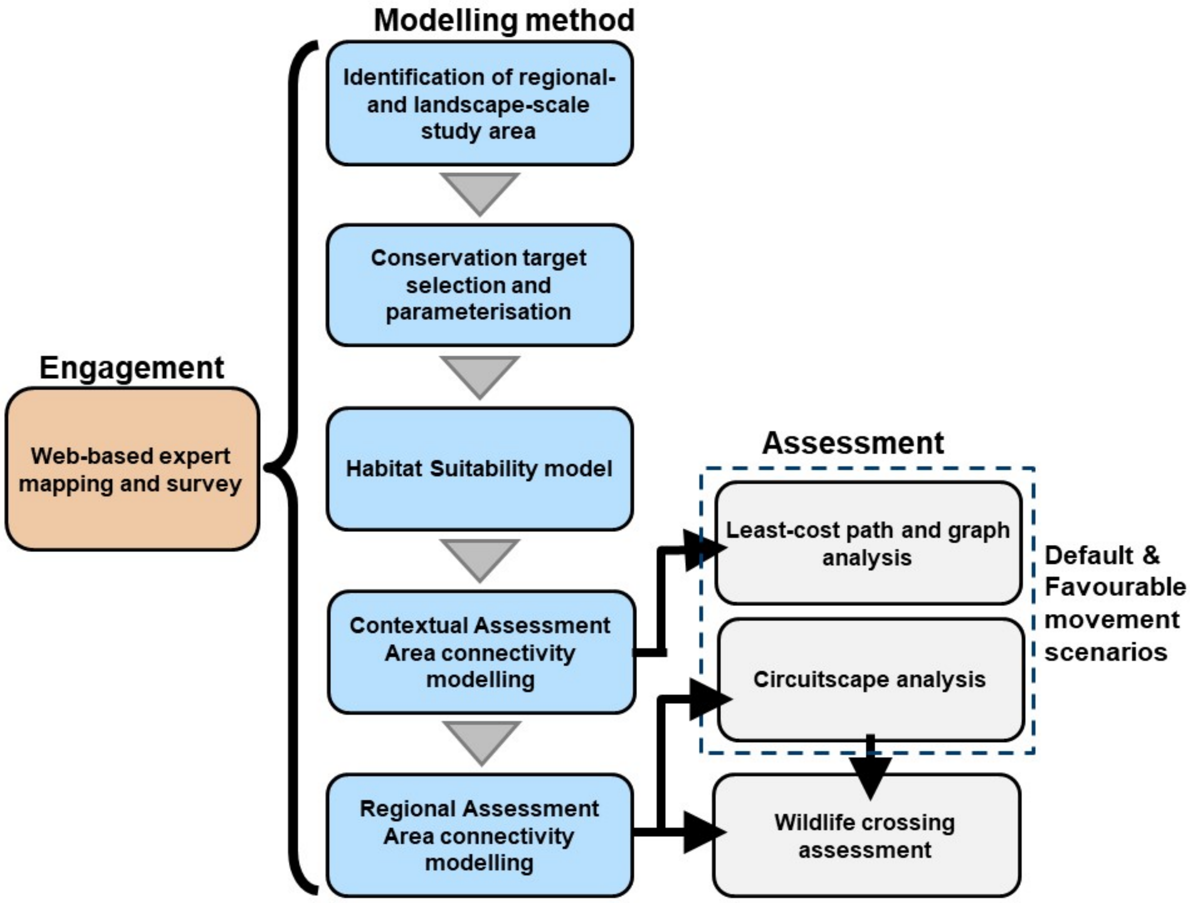

Figure 4: General schematic of processing steps used in this study.

The analysis was primarily limited to publicly available spatial data. With the majority of species occurrence data for obtained from the Global Biodiversity Information Facility (GBIF) www.gbif.org (Global Biodiversity Information Facility, 2021) and the environmental and climate data derived from freely available global spatial datasets.

2.2. Contextual and Regional Assessment area selection

The proposed highway passes through an ecologically complex landscape with diverse habitat types and topography, including the globally significant Great Lakes system. This area contains numerous protected areas (PA), key biodiversity areas (KBA), and Important Bird and Biodiversity Areas. The ecological uniqueness of the Great Lakes system is recognised by the World Heritage Committee. To capture large-scale ecological processes, a Regional Analysis Area (RAA) was defined, encompassing a 15 km buffer around the project's alignment and including all protected areas and Internationally Recognised Areas (e.g., Natural World Heritage Sites, KBAs or Ramsar sites) that intersect with this 15 km buffer. These areas are: part of the Kikuyu Escarpment Forest, Aberdare National Park, Kinangop Grasslands, habitat surrounding Longonot National Park, Hell's Gate National Park, the Mau forest complex, the Central Rift Valley Lakes (Naivasha, Elementeita, Nakuru) and the headwaters of river systems flowing into Lake Baringo and Lake Victoria (Ojwang' et al., 2017). These locations are intersected by the highway or are in close proximity to it. This RAA component of the study (Figure 4; Figure 5), which is common to other studies which contributed to the ESIA. It was first delineated by The Biodiversity Consultancy as a Discrete Management Unit (DMU) for critical habitat screening (Bennun et al., 2018). Further details around the choice and description of the study area is presented elsewhere in the ESIA.

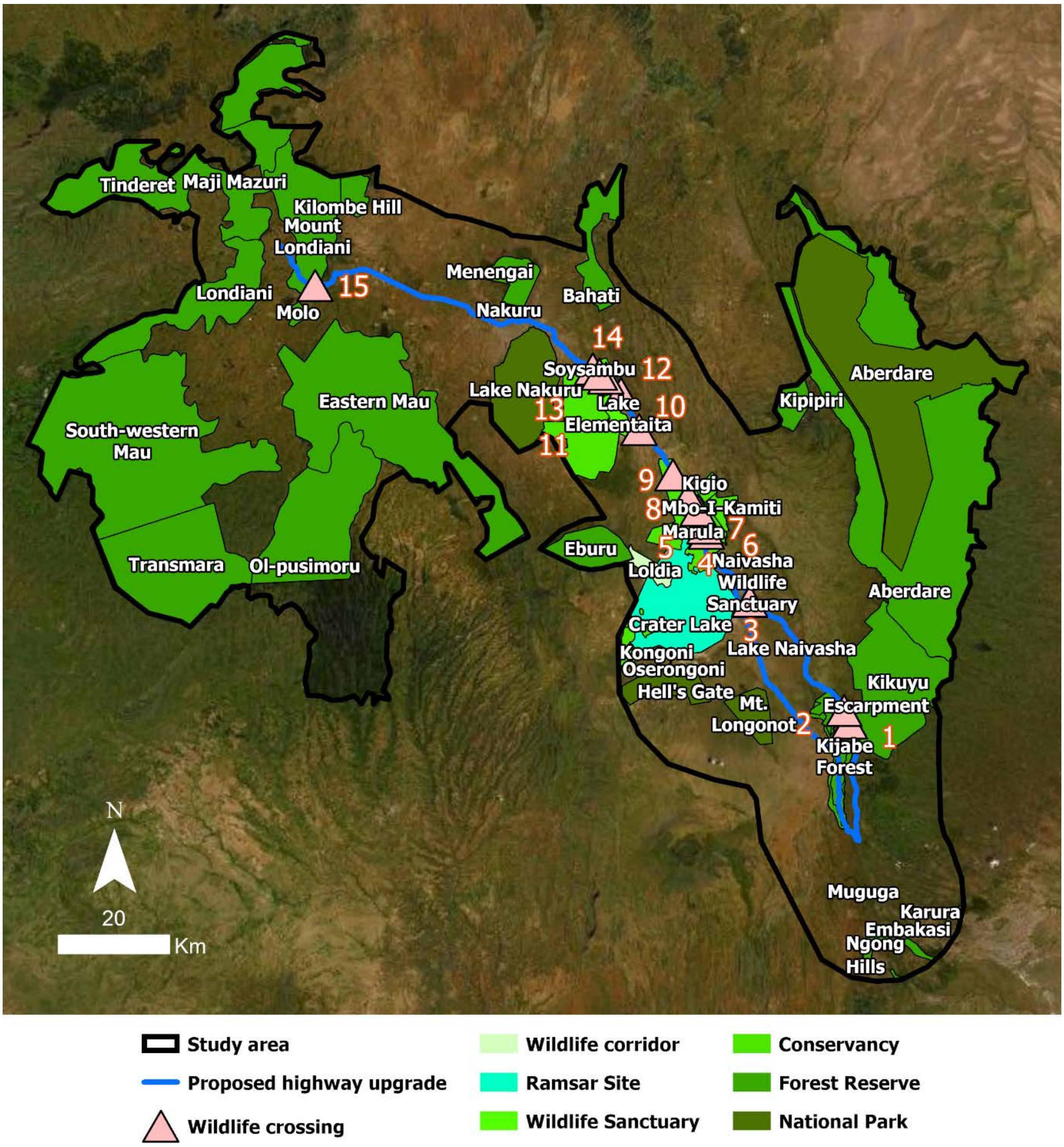

Figure 5: Regional Assessment Area (RAA) used in ESIA (more detailed mapping of specific areas are presented in other figures in this document).

The CAA is a 170 km buffer of the RAA which was selected with the following in mind (Figure 6):

- Sufficient total number of species occurrence points for each of our conservation targets to support robust modelling by covering areas where clusters of occurrence points exist.
- Ensure that a broad range of environmental variation is captured with the occurrence points representing the species niche.
- Cover any key/large habitats that are truncated by the RAA such as the Kikuyu Escarpment Forest.
- Encompass key wildlife movement routes from outside of the study site.
- Capture the importance of core habitat locations in terms of connections into and outside of the RAA.

At broader scales, the dominant biome in the RAA, and relevant to our conservation target species is savannah (Miller et al., 2016).

The outputs from the CAA are primarily required to support an understanding of the importance of the relationship between the RAA and the surrounding environment.

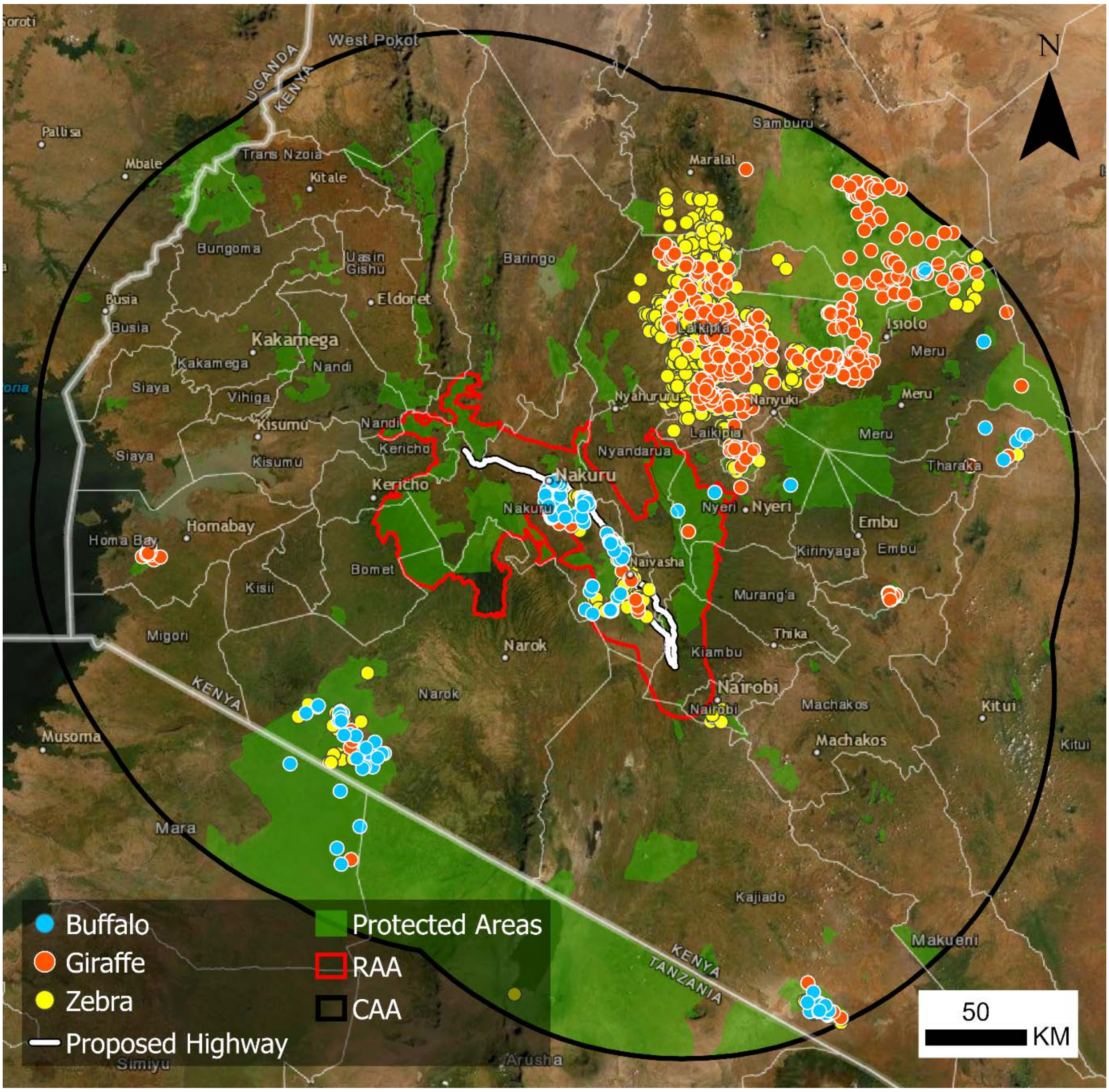

Figure 6: Overview of RAA and CAA study extents along with the presence only data for the three species modelled.

2.3. Web-based expert mapping and survey

A web based, public participatory GIS (PPGIS) expert survey was prepared to obtain insights from experts and stakeholders regarding species selection, model parameters and feedback on the preliminary analysis (Figure 7). For this the Maptionnaire web-based mapping software was used https://maptionnaire.com/. A key reason for the using an online survey approach was due to COVID making running face-to-face workshops impossible.

Figure 7: Screenshots of the Web-Based PPGIS survey using Maptionnaire, an interactive, online, crowdsourcing, geospatial web mapping application, to obtain feedback from the local experts. See Appendix B for more details. The survey can be accessed via this link: https://new.maptionnaire.com/q/7bbr6zf74i6y.

The survey was presented in an online workshop held with approximately 28 local expert and stakeholder attendees which included wildlife experts, environmental NGOs and private land conservancy representatives (a list of the attendees can be found in Appendix A). We also distributed the survey online to experts who could not attend the workshop but have an interest in the area.

The survey was divided into six main sections: (1) contact details, (2) species distribution modelling inputs, (3) protected area correction, (4) species occurrence data, (5) preliminary species distribution modelling habitat suitability outputs and (6) additional comments. The respondent's contact information was collected in Section 1 to facilitate post-survey communications (see Appendix B for more details). In section 2, the respondents were asked to rate the level of importance of the explanatory variables used to model habitat suitability for the key species and to bring up any missing key variables. In addition, the respondents were also asked to provide an estimate of daily foraging ranges and the maximum interpatch dispersal distance for each of the three key species. The level of confidence for each movement distance estimate was also requested. In section 3, the respondents were asked to provide feedback on corrections to the World Database on Protected Areas (WDPA) dataset which we found to contain topographical inconsistencies in parts of the datasets. Tools were provided for the experts to digitize missing protected areas and to mark protected areas that no longer exist, contain errors, were fenced, or those that do not offer protection or are not properly managed such as 'paper parks'. In section 4, the respondents were provided with tools to mark areas where they were able to provide additional occurrence data for the three key species. The preliminary outputs from the habitat suitability modelling for buffalo, giraffe and zebra were presented for the experts to critically assess and provide feedback or report any critical observations that we can use to improve the modelling process. In the final section, the experts were provided with tools to mark points, lines or areas where they would like to provide any further comments and recommendations.

There was a total of 17 responses, out of which, only seven contributed feedback to the survey in the first three sections. Hence, the responses were used to facilitate the selection of explanatory variables for the modelling and to make minor updates to the protected area dataset. More details on how the responses were incorporated into the analysis are described in the relevant sections.

2.4. Conservation target species and parameterisation

2.4.1. Conservation target species selection

Three conservation target species were chosen for the analysis:

- Giraffe (*Giraffa spp.*)
- Plains Zebra (*Equus quagga*, formerly known as *Equus burchelli*)
- African Buffalo (*Syncerus caffer)*

These species are of key conservation concern in the region, have different ranges and respond to human disturbance differently and are likely to be impacted by the highway development. While the Giraffe is of conservation significance, buffalo and zebra populations represent key ungulate species within RAA ecosystem. The selection of these species was validated in an expert workshop and via the web-based expert survey. Further details around the choice of species and analyses of other important species for conservation is presented elsewhere in the ESIA. Hereafter, throughout the report the three conservation targets are referred to by their common names: Giraffe, Zebra and Buffalo.

For Giraffe (Giraffa spp.) recent studies have shown that there are multiple giraffe subspecies that occur throughout their range ((Fennessy et al., 2016; Petzold et al., 2020; Winter et al., 2018)). The three subspecies of Giraffe that are found in Kenya are: Masai giraffe (G. tippelskirchi), reticulated giraffe (G. reticulata) and Nubian giraffe (G. camelopardalis camelopardalis). All are listed on the IUCN red list as endangered. Masai giraffe is the only naturally occurring sub-species within the RAA and occurs in open areas within the Naivasha ecosystem, whereas Nubian giraffe occur in fenced areas within Nakuru, namely Lake Nakuru National Park, Soysambu Wildlife Conservancy, Kigio Wildlife Conservancy, and Tindress Farm. Reticulated giraffe mainly occur in northern Kenya.

While, the Masai Giraffe is most relevant to the road corridor ESIA, it is represented by a single occurrence point in the RAA and two occurrence points in the CAA at the required accuracy for modelling in the GBIF database (Appendix C). In contrast, 335 occurrence points with the required accuracy are available in the GBIF database, however, they have no subspecies defined. In addition, a number of records appear to be incorrectly labelled (Appendix C). To avoid potential confusions between available species records found in Kenya, we modelled connectivity for Giraffe presence as a single species with no distinction between subspecies. This was also conducted to address a lack of data on its distribution if northern occurrence records which are likely to be associated if Reticulated Giraffe records are removed. Our modelling will thus represent an overestimate of suitable habitat for Masai Giraffe, but there are no other options because modelling the current data at the subspecies level would not work because there are insufficient point locations.

2.4.2. Literature review and expert survey parameter value identification

We used a combination of expert opinion obtained from the (i) web-based survey (PPGIS) and (ii) data from the literature describing species movement to parameterise both the species distribution models and the connectivity models. The four parameters' values identified were:

- estimated daily foraging range (km^2) which was used to parameterise the moving window filter applied to the environmental explanatory data used as an input into the species distribution model.
- home range size (km^2) used to parameterise the bias map, to address occurrence point bias, which is an input into the species distribution model.
- minimum patch size (km^2) to identify the smallest patches of habitat that the species can occupy as an input into the connectivity model.
- interpatch dispersal distance (km) which represents the maximum distance which individuals can move between patches as an input into the connectivity model.

We reviewed majority of movement studies available in the peer-reviewed academic literature on the three species, including all subspecies which are found in similar savanah biomes to our conservation targets using a systematic search (28th June 2021). We conducted the literature review using Scopus and the search string "TITLE-ABS-KEY ("home range" OR "home-range" AND "syncerus caffer" OR "African buffalo") for Buffalo, "TITLE-ABS-KEY ("home range" OR "home-range" AND "equus quagga" OR "equus burchelli" OR "plains zebra") for Zebra and "TITLE-ABS-KEY ("home range" OR "home-range" AND "giraffa" OR "giraffe") for Giraffe. The number of results were 20 articles for Buffalo, 22 articles for Giraffe, and 6 articles for Zebra. Separately, we also searched for daily movement distance studies on Scopus by replacing "home range" OR "home-range" from above with "daily movement" OR "foraging" for each of the 3 species, and recorded 29, 49 and 67 articles for Buffalo, Giraffe and Zebra respectively. We also did a search on Google Scholar using the same key words for home range and daily movement studies for all 3 species, receiving more than 10,000 results each with the Giraffe returning 31,600 results on Google Scholar, for home-range studies. In the interest of time, we only reviewed the first page (10 articles per page) of Google Scholar results for each species. Finally, we also did an unsystematic search using Scopus based only on species name.

We treated an article as relevant to our study if they were an empirical study on home range or foraging distance (or similar). Articles which may have discussed the importance home range by didn't include empirical data were removed. The biomes where these studies were located was identified based on the biome boundaries delineated by Miller et al. (2016). We reviewed 18 studies that provided relevant values on the different movement parameters (Table 1, Table 2). The majority of these were GPS collar radiotracking studies. These studies characterised movement from a variety of temporal and spatial scales including daily, annual and wet versus dry season. Where possible (i.e. if data were available), we calculated a range of descriptive statistics for each study. In most cases, the studies calculated an area-based statistic. These were converted to linear statistic based on the radius/diameter of a circle for certain parameters. While categorisation into different seasons was self-identified by the study.

The daily movement or foraging distances represent the total area used by an individual or a group of individuals in a day (Table 1). The various studies calculated this in a variety of ways. Commonly through the application of radiotracking where GPS fixes at specific time-intervals within a single day are converted to an area estimate using the local convex hull algorithm (Stark et al., 2017). Unlike studies on annual home range, there were very few studies on daily movement (n=5) appropriate for parameterising our model. There was single study on Buffalo and 2 studies each for Giraffe and Zebra. In addition, none of the studies were from Kenya and only one of the studies was from neighbouring country – Tanzania (Roug et al., 2020). Hence the literature review data was supplemented by the expert survey.

Table 1: Daily movement and foraging areas for the three focal species identified from the peer-reviewed literature. A total of 5 movement studies were identified from the literature relevant to determining daily movement and foraging area.

Subspecies	Location	Vegetation biome (Miller et al., 2016)	Mean annual daily (km^2)	Max annual daily (km^2)	Min annual daily (km^2)	Mean dry season (km^2)	Max dry season (km^2)	Min dry season (km^2)	Mean wet season (km^2)	Final annual value used for comparison (km^2)	Source
African buffalo (*Syncerus caffer*)	Ruaha National Park, Tanzania	Savannah/ Deciduous Woodland/ Other	66.48 r= 4.6 km	149.57 r= 6.9 km	40.72 r= 3.6 km	55.42 r= 4.2 km			75.43 r= 4.9 km	66.48	(Roug et al., 2020)
South African giraffe (*G. g. giraffa*)	Khamab Kalahari Nature Reserve, South Africa	Savannah	78.54 r= 5.1 km							78.54	(Deacon and Bercovitch, 2018)
Angolan giraffe (*G. giraffa angolensis*)	Northern Namib Desert, Namibia	Desert/ Semi-desert				10.99 r= 1.87 km	172.5 r= 7.41 km	0.011 r = 0.06 km			(Fennessy, 2009)
Plains zebra (*Equus quagga*)	Kruger National Park in South Africa Kruger National Park in South Africa	Savannah	47.96 r= 3.91 km	99.5 r= 5.63 km	21.7 r= 2.63 km					26.02	(Owen-Smith and Martin, 2015)
	Kruger National Park in South Africa	Savannah	4.08 r= 1.14 km	11.2 r= 1.89 km	0.64 r= 0.45 km						(Owen-Smith et al., 2015)

For annual and seasonal home range studies we identified 18 studies (Table 2), with seven studies on Buffalo, five on 5 Giraffe and six on Zebra. None of the studies were from Kenya, with the majority of studies from Botswana (n= 4), South Africa (n=8) and two in neighbouring Tanzania. However, these studies are useful as the biomes are similar. Like daily movement, the majority of studies used GPS collars and the convex hull algorithm to measure home range area.

Table 2: The annual movement and foraging home ranges (HR) for the three focal species identified from the peer-reviewed literature. A total of 18 movement studies were identified from the literature.

Species	Location	Vegetation biome (Miller et al., 2016)	Method	Herd size	Annual HR			Dry season HR			Wet season HR			Source
					Mean (km^2) (n=9)	Max (km^2) (n=10)	Min (km^2) (n=9)	Mean (km^2) (n=8)	Max (km^2) (n=8)	Min (km^2) (n=7)	Mean (km^2) (n=9)	Max (km^2) (n=9)	Min (km^2) (n=8)	
African buffalo (*Syncerus caffer)*	Kruger National Park, South Africa.	Savannah/ Other	Observation	Mean: 248		120			138.04			127.76		Funston et al., (1994)
	Kruger National Park, South Africa	Savannah/ Other	Unspecified	Up tp 1000	53	65	39							Winnie et al. (2008)
	Kruger National Park, South Africa	Savannah/ Other	Collared females	Unspecified				72	89	55	147	166	128	Getz et al. (2007)
	Klaserie Private nature Reserve, South Africa	Savannah/ Other	Observation	100-400	240.13	327.04	170.68	33.8			17.61			Ryan et al. (2006)
	Ruaha National Park, Tanzania	Savannah/ Deciduous Woodland/ Other	Collared females	700-1000				83.63	149	35	176.4	256	50	Roug et al. (2020)
	Caprivi Strim, Namibia	Savannah	Collared males and females	3-500				57			138			Naidoo et al. (2012)
Cape buffalo (*Syncerus caffer caffer*)	Okavango Delta, Northern Botswana	Savannah	Collared females	50-300							181.7	300	100	Bennitt et al. (2016)
South African giraffe (*G. g. giraffa*)	Khamab Kalahari Nature Reserve, South Africa	Savannah	Collared females	Total population size of 118	206	437.71	65.16	210.9	471.52	55.18	201.1	534.1	42.93	Deacon & Smit (2017)
	Kruger National Park, South Africa	Savannah	Unspecified	Unspecified	282									du Toit (1990)
Angolan giraffe (*G. giraffa angolensis*)	Northern Namibia Desert, Namibia	Desert/Semi-desert	Collared males and females	Unspecified	244.7	1950	20.7							Fennessy (2009)
West African giraffe (*Giraffa c. peralta*)	Niger and its peripheral regions, Northeast Africa	Savannah	Collared males and females	Total population size of 63	611	1564	127	90.9	133.9	44.9	39.9	66.4	31.7	Le Pendu & Ciofolo (1999)
Masai Giraffe (*Giraffa tippelskirchi*)	Lake Manyara and Tarangire National Parks, Tanzania	Savannah	Photographic mark-recapture surveys	Unspecified	122	144.1	110.4							Knüsel et al (2019)
Burchell's zebra (*Equus burchelli antiquorum*)	Makgadikgadi Pans National Park, Botswana.	Savannah	Unspecified	More than 30					1956	1356				Brooks (2005)
Plains zebra (E*quus quagga* a.k.a. *Equus burchelli*)	Okavango Delta, Botswana	Savannah	Collared females	Unspecified				93.8						Bartlam-Brooks et al. (2013)
	Okavango Delta, Botswana	Savannah	Collared females	Several thousands							6650	9000	4000	Bennitt et al. (2019)

	Ngorongoro Crater and Serengeti, Tanzania	Savannah	Collared males and females	Unspecified		250	80		600	4		400	3	Klingel (1969)
	Kruger National Park in South Africa	Savannah	Collared females	6-7	120.76	345.5	35							Owen-Smith & Martin (2015)
	Kruger National Park in South Africa	Savannah	Collared females	6-8	258.75	446	148	63.61	91.1	37.7	41.58	52	29.4	Owen-Smith et al. (2015)

As can be seen in Table 1 and Table 2 there were no studies from Kenya and very few studies from neighbouring countries. While there were a significant number of studies describing annual and wet and dry season home ranges, we found very few studies on daily foraging ranges and few studies which were relevant to interpatch dispersal distances thresholds which could be used to support our modelling. Using the web-based survey we gathered estimates on the (i) interpatch dispersal distance and (ii) daily foraging range from local experts to address these shortcoming (Table 3). In addition to

The final values used in the modelling are described in Table 4 and further explanation on how they were chosen are found in the sections where they are used. As can be seen by the sample size of both expert opinion and the literature, the data and knowledge required to parameterise our models were scarce.

Table 3: (a) Interpatch dispersal distance and (b) daily foraging range collected from (n=3) local experts via web-based expert survey. Italicized values were provided by the respondents and converted accordingly. Note that one expert did not provide feedback on all species. Confidence was self-assigned based on a 5-point Likert scale (commonly used in social surveys): 1 = Not at all confident, 2 = a little confident, 3 = somewhat confident, 4 = Quite confident, 5 = Extremely confident.

	Buffalo			Giraffe			Zebra		
a) Interpatch dispersal distance	**Area (km²)**	**Distance (km) as radius**	**Confidence**	**Area (km²)**	**Distance (km) as radius**	**Confidence**	**Area (km²)**	**Distance (km) as radius**	**Confidence**
	1256.6	*20*	A little confident	615.8	*14*	somewhat confident	1256.6	*20*	A little confident
	5	1.26	somewhat confident	*100 - 300*	5.64 - 9.77	Quite confident	*100 – 500*	5.64-12.6	A little confident
	2 – 4	0.8-1.13	A little confident	*10*	1.78	A little confident			
b) Daily foraging range	12.57 - 28.27	*2-3*	Quite confident	50.27 - 113.1	*4-6*	Somewhat confident	78.54 - 314.16	*5-10*	A little confident
	3	0.98	Quite confident	*10*	1.78	Quite confident	*1-2*	0.56-0.8	A little confident
	1-2	0.56-0.8	A little confident	*0-1*	<0.56	Somewhat confident			

Table 4: Final values from literature review and Maptionnaire for modelling. Radius (r) value represents the values used for environmental variable surfaces. For our ruleset we chose descriptive statistics which removed the large influence of outliers in our small sample. For more details on what each parameter represents and how they are used in the modelling see the proceeding sections.

Parameter	Buffalo	Giraffe	Zebra	Ruleset
Bias file - Home Range (average) (km^2)	132	151	190	Median value of the mean Annual home range, Dry season home range and Wet home range.
Patch size - Home range (overall min) (km^2)	45	37	35	Smallest value of average minimum for Buffalo and Giraffe, and maximum value of overall minimum for Zebra
Moving window - Estimated foraging range (km^2)	3 r = 0.9772 km	3 r = 0.9772 km	4 r = 1.1284 km	Median value to nearest kilometer from experts
Interpatch-dispersal distance - indicative minimum (km)	20	14	20	Overall maximum from experts

2.5. Habitat suitability modelling

2.5.1. Occurrence data and pre-processing

Species occurrence data for our conservation targets were primarily obtained from the Global Biodiversity Information Facility (GBIF) www.gbif.org (Global Biodiversity Information Facility, 2021) (Table 5). GBIF is a free and open access biodiversity portal. Records from the past 11 years which were recorded in Kenya, Tanzania and Uganda were selected and clipped to the extent of our study area. They were filtered for coordinate uncertainty (≤ 200 m) to reflect the spatial resolution of the GIS data.

Supplementary occurrence data were also included from the (i) camera trap study conducted from 17th of February to 10th of June 2021, (ii) occurrence data from the biodiversity baseline investigation on mammals carried out by Flora Fauna & Man Ecological Services (FFMES) and from (iii) wildlife census points from Soysambu conservancy (Appendix D). These data accounted for a small proportion of the total occurrence dataset, however, were all in the RAA and therefore made important contributions to modelling habitat suitability around the highway upgrade.

As we were aware of other sources of existing non-publicly available datasets such as published in Ojwang et al.'s (2017) report, we presented the GBIF occurrence data in the web-based expert survey as an interactive web-map and requested respondents to identify locations with missing occupancy data. However, we were not successful in obtaining any new data.

All the occurrence points were then spatially filtered within a 200 m radius to prevent spatial auto-correlation using the "Spatially rarefy occurrence data for SDMs" tool in SDM Toolbox (Brown, 2014).

In the final step a bias file was created to address one of the key limitations of presence-only data, which is the effect of sample selection bias associated with some areas in the landscape being sampled more intensively than others (Phillips et al. 2009). We buffered around each occurrence point using based on each species home range using the sample by distance from observation points tool in SDM Toolbox (Brown, 2014). In this case we used the median value of the mean annual, dry and wet season home range (Table 4). We used this value to remove the influence of extremely large or small home range values recorded for each species distorting the final values.

Table 5: Total number of occurrence points for each conservation target. *Locally sourced-supplementary occurrence points.

Species	Occurrence points from GBIF			Points from Camera traps*	Points from FFMES survey*	Points from Soysambu*	Final Points
	Raw Points	After filtering for ≤ 200 m uncertainty	Spatially rarified 200m				
Buffalo (*Syncerus caffer*)	504	127	112	24	14	6	156
Giraffe (*Giraffa spp.*)	1583	1013	400	13	13	4	430
Zebra (*Equus quagga*)	1565	1034	892	47	114	10	1063

The location of all the occurrence points used for the modelling are shown in Figure 8. A key issue with the available occurrence data is that a large percentage were only available at low spatial accuracies. For example, the total number of GBIF data for the Giraffe in the study area is 1583, but after filtering to less than 200 m accuracy only 400 points were suitable. It is common, for example, for GBIF data to only be recorded using the centroid of a plot or protected area. Such low-accuracy data can’t be used for species distribution modelling.

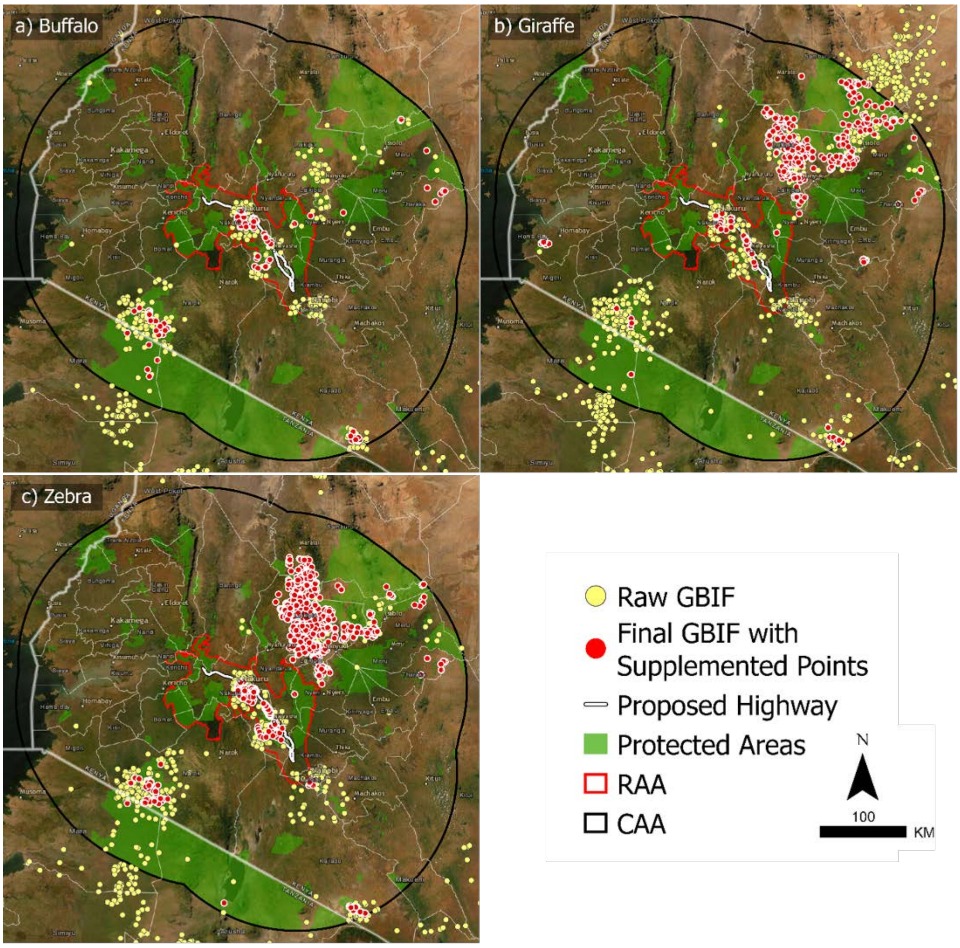

Figure 8: Comparison of the raw GBIF and final species occurrence points (suitable GBIF points plus locally-sourced supplementary occurrence points) used for modelling for (a) Buffalo, (b) Giraffe and (c) Zebra.

2.5.2. Environmental variables

Environmental explanatory variables were derived from a range of sources to characterise the abiotic factors which determine habitat for each target species (Table 6). These variables included climate (e.g. mean annual temperature), topography (e.g. slope) and land cover (e.g. land use and vegetation greenness). All environmental variables were derived from publicly available datasets. The majority of the data was current for 2020, while other data such as elevation and climate represent long time scale phenomenon.

Some datasets such as those derived from - the Bioclim climatic data only required resampling to 200 m and clipping to the study area, however, a number of datasets were pre-processed or acquired from Google Earth Engine. Google Earth Engine (GEE) is an open source, cloud-based platform that has virtually unlimited processing and storage capacity, and an extensive library of satellite remote sensing data and spatial data products such as land cover maps (Gorelick et al., 2017; Mutanga and Kumar, 2019). Pre-processing methods including:

- Derivation of vegetation indices such as the Normalised Difference Vegetation Index (NDVI).
- Application of a moving window filter (i.e. mean, majority) for a specified area identified by the daily movement range (Table 4).

- Distance to a specific feature such as a water body calculated with Euclidian distance.
- Calculation of slope from a digital elevation model.

A number of indices (e.g. NDVI) were derived from Landsat 8 data (Table 6). Before calculating these indices, the Landsat data were processed to derive a multi-date cloud free composite surface reflectance product representing the median value for any cloud-free pixel between 01-01-2020 and 31-12-2020 (Ang et al., 2020).

The moving window/convolution filter (Whitehead et al., 2015) calculates statistics (i.e. mean, maximum) for a pixel and its neighbours at a specific distance. For our study, we used the daily movement range of each species to define the neighbourhood distance.

In the final step, all data were aggregated to 200 m pixel resolution and clipped to the study area.

Table 6: Full list of explanatory variables used for the species distribution modelling. For each species a subset of the variables was used. The 3000/4000 indicates that the moving window/convolution was filter applied to the variable using the daily home range area (km^2).

Explanatory variables	Description (Data source)	Unit	Sensor	Time	Original pixel size (m)	Source	Weblink
NDVI	Normalized Difference Vegetation Index (NDVI)	NDVI	Landsat 8	2020	30	Multi-date cloud free mosaic Landsat – GEE	Link to GEE code
NDVI_3000/ 4000	Mean NDVI in a 3000 m^2 or 4000 m^2 area moving window mean filter.	NDVI	Landsat 8	2020	30	Multi-date cloud free mosaic Landsat – GEE	Link to GEE code
Wetness	Soil moisture, water and other moist features.	Tasselled cap transformation (TCT) index	Landsat 8	2020	30	Multi-date cloud free mosaic Landsat – GEE	Link to GEE code; Link to methods
Distance to water	Distance to water from every non-water pixel	Meters	Landsat 8	2020	30	NDWI layer - GEE	Link to GEE code
Slope	The slope of a cell (in degrees) derived from NASA SRTM Digital Elevation	Degrees	SRTM	2000	30	NASA SRTM Digital Elevation - GEE	Link to GEE code Link to dataset
Elevation	Digital Elevation	Meters	SRTM	2000	30	NASA SRTM Digital Elevation - GEE	Link to GEE code Link to dataset
Topographic Ruggedness (Roughness)	Topographic ruggedness standard deviation in a 3000 m^2 or 4000 m^2 area moving window	Meters	SRTM	2000	30	NASA SRTM Digital Elevation - GEE	Link to source dataset
Distance to protected areas	Distance to protected areas	Meters			Vector	Protected Planet: The World Database on Protected Areas (WDPA)	(UNEP-WCMC and IUCN, 2021a)
Protected areas_3000/4000	Total percentage of protected areas in a 3000 m^2 or 4000 m^2 area moving window	Percent			Vector	Protected Planet: The World Database on Protected Areas (WDPA)	(UNEP-WCMC and IUCN, 2021b)
Landcover	Copernicus Global Land Cover Layers (GEE)	Classes	PROBA-V	2019	100	Copernicus Global Land Cover	Link to GEE code; Link to dataset

Distance to open forests	Distance to open forest; evergreen and deciduous trees with top layer comprising of 15-70 % tree cover and second layer a mixed of shrubs and grassland	Meters	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Distance to closed forests	Distance to closed forest; evergreen and deciduous trees with canopy cover >70 %.	Meters	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Distance to closed and open forests (combined)	Distance to closed forest; evergreen and deciduous trees with canopy cover >70 %, and open forest; evergreen and deciduous trees with top layer comprising of 15-70 % tree cover and second layer a mixed of shrubs and grassland	Meters	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Open forests_3000/4000	Percentage of sum of open forest in a 3000 m^2 or 4000 m^2 area moving window.	Percentage	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Closed forests_3000/4000	Percentage of sum of closed forest in a 3000 m^2 or 4000 m^2 area moving window.	Percentage	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Closed and open forests_3000/4000	Percentage of sum of closed and open forest 3000 m^2 or 4000 m^2 area moving window	Percentage	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Distance to built up	Distance to urban / built up. Land covered by buildings and other man-made structures.	Meters	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Distance to livestock	Livestock data was substituted with Sparse Vegetation, Shrub, Herbaceous Vegetation and Herbaceous Wetland land cover from Copernicus Global Land Cover Layers. The distance to these pixels were calculated.	Meters	PROBA-V	2019	100	Copernicus Global Land Cover	Link to source dataset
Distance to roads	Roads data were extracted from OSM. 1. Motorway 2. Primary, secondary and, tertiary roads 3. Unclassified minor roads 4. Residential roads 5. Motorway, primary and secondary link 6. Trunk 7. Track 8. Service roads	Meters			Vector	Open Street Map	Link to dataset
Landform	The SRTM Landform dataset provides landform classes created by combining the Continuous Heat-Insolation Load Index (SRTM CHILI) and the multi-scale Topographic Position Index (SRTM mTPI) datasets. It is based on the 30m SRTM DEM	Landform Classes	SRTM	2000, 2006 – 2011	90	Global SRTM Landforms	Link to dataset
Landform_3000/4000	Majority of landform classes in 3000 m^2 or 4000 m^2 area moving window	Classes	SRTM	2000, 2006 – 2011	90	Global SRTM Landforms	Link to dataset
Mean annual temperature	The annual mean temperature.	Degrees Celsius	Weather stations	1960 – 1991	1000	WorldClim V1 Bioclim	Link to GEE code; Link to dataset
Mean annual temperature of the warmest quarter	The maximum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).	Degrees Celsius	Weather stations	1960 – 1991	1000	WorldClim V1 Bioclim	Link to GEE code; Link to dataset

Mean annual temperature of the coldest quarter	The minimum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).	Degrees Celsius	Weather stations	1960 – 1991	1000	WorldClim V1 Bioclim	Link to GEE code; Link to dataset
Mean annual precipitation	The mean monthly precipitation values.	Millimeters	Weather stations	1960 – 1991	1000	WorldClim V1 Bioclim	Link to GEE code; Link to dataset
Precipitation Seasonality	This is a measure of the variation in monthly precipitation totals over the course of the year. This index is the ratio of the standard deviation of the monthly total precipitation to the mean monthly total precipitation (also known as the coefficient of variation) and is expressed as a percentage.	Percent	Weather stations	1960 – 1991	1000	WorldClim V1 Bioclim	Link to GEE code; Link to dataset
Nightlights_Mean_3000/4000	Mean nightlights (average Day/Night Band (DNB) radiance values) in a 3000 m^2 or 4000 m^2 area moving window.	Radiance	Visible Infrared Imaging Radiometer Suite (VIIRS)	2020	500	VIIRS Nighttime Day/Night Band Composites Version 1	Link to GEE code; Link to dataset

One of the more important explanatory layers for modelling the conservation target species' distribution was the protected area layer. This dataset was composed primarily of the World Database on Protected Area (WDPA) data (UNEP-WCMC and IUCN, 2021). However, we also included private conservancy datasets which delineated privately managed protected areas, especially within the RAA. Conservancies included in this dataset include the Soysambu Wildlife Conservancy, Marula Estate, Crater Lake Conservancy and Kigio Wildlife Conservancy (RLCA, 2016).

A key issue with using the WDPA dataset was positional errors meant for some locations the protected area boundaries did not align with other features on the ground represented by existing maps, such as true colour imagery and land cover maps (Figure 9b). The positional error discrepancy observed amounted to ~4km in some locations. In Appendix E we describe in more detail some of the issues and the method we used for manually fixing the layer. We fixed 158 polygons out of the total 311 polygons representing protected areas. A key concern is that we were not very confident in deducing the accuracy of 140 polygons as many of those polygons did not correspond to features on the ground (i.e. a forest boundary).

a) b)

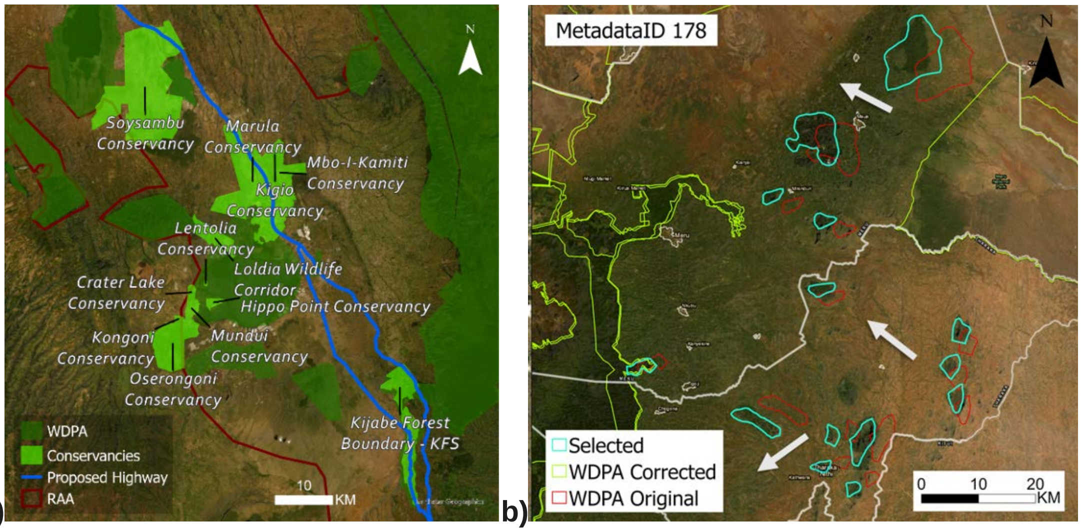

Figure 9: a) Private conservancies missing from World Database on Protected Areas. b) Example of alignment errors in the World Database on Protected Areas which were corrected (see Appendix E for more information).

To address the uncertainty in the protected area layer, in the web-based expert survey we also asked respondents to comment on the edits we made and identify any missing protected area locations. However, none of the responses received were specific to a particular protected area. Unfortunately, this dataset appears to be an ongoing problem for conservation planning in Kenya (see Appendix E for more information).

2.5.3. Environmental variable selection

The selection of variables for modelling the distribution of each species was based on a literature review, the importance of the variables based on their percent contribution to the MaxEnt model and on correlation between variables.

Firstly, for each species we reviewed the relevant literature and identified 23 candidate explanatory variables for which we had spatial data (Table 7, Table 8 and Table 9). The importance of these variables was then confirmed with the web-based expert survey whereby experts were asked to rate the importance of each variable (Appendix B). The survey found that experts generally confirmed the selection of the variables from the literature. The survey also asked respondents to nominate any missing variables. Three suggestions for variables to be included were fence lines, tree species and the presence of livestock. While we recognise these variables are important and likely to affect species distribution, however, spatial data were unavailable for fence lines and tree species, and existing publicly available spatial data on livestock were not available at the appropriate spatial resolution. Given the importance of fence lines for connectivity, we requested respondents to map or identify fence line datasets in the web-based expert survey. Unfortunately, the survey confirmed that no such dataset exists, and needs to be carefully considered during the placement of the crossings i.e. fences might need upgrading, and put in place.

We reduced the 23 candidate variables to minimize the correlation among explanatory variables (Merow et al., 2013) and overfitting. We performed a multicollinearity test for the environmental spatial datasets (Appendix F). We also ran MaxEnt with the original set of variables to characterise the percent contribution of each candidate variable. We then qualitatively removed correlated variables, retaining variables with the highest percent contribution and those that were described as important in the literature (Table 7, Table 8 and Table 9). The number of variables used for the Buffalo, Giraffe and Zebra were 13, 15 and 15 respectively.

Table 7: Variables used for modelling suitable habitats for Buffalo. Details of the percentage contribution from model, multicollinearity tests and the significance of variables based on literature are compiled below. The rows are ordered by the final percent contribution (highest to lowest) and the rank column represents the ranking when all variables were used. The AUC for the model with every variable and the final variable set is also presented.

Rank	Variable	Percent Contribution		Highly correlated variable(s) (correlation value)	Influence, strength, from literature	Supporting literature
		Every variable	Final			
	AUC	0.858	**0.866**			
1	Distance to Protected areas	18.9	**19.1**		Moderate	(Bhola et al., 2012; Matawa et al., 2012)
3	Distance to closed forest	10.9	**16**	Distance to open forests (0.56), Distance to closed+open forests (0.59)		No literature found
2	Distance to roads	14.9	**13.9**	Distance to built-up (0.57)		No literature found
5	Elevation	10	**12.3**	Seasonal precipitation (-0.53), Mean temperature of the coldest quarter (-0.96), Mean temperature of the warmest quarter (-0.98), Mean annual temperature (-0.98)		(Weel et al., 2015)
6	Distance to open forest	9.1	**9.6**	Distance to closed forest (0.56), Distance to closed+open forests (0.98), NDVI (-0.55), NDVI_3000 (-0.59)		No literature found
4	Distance to water body	10.8	**9.1**		Strong	(Bennitt et al., 2015; Hopcraft et al., 2012; Matawa et al., 2012; Naidoo et al., 2012; Sianga et al., 2017; Young et al., 2020)
8	Mean annual precipitation	3.2	**5.3**	Seasonal precipitation (-0.5)	Strong (rainfall)	(Bennitt et al., 2015; Hopcraft et al., 2012; Hughes et al., 2017; Naidoo et al., 2012; Ogutu et al., 2016)
7	NDVI_3000	3.6	**4.4**	Distance to open forests (-0.59), Distance to closed+open forests (-0.62), NDVI (0.93)	Strong (NDVI)	No literature found
9	Nightlights mean_3000	2.6	**3.8**			No literature found
10	Landform_3000	2.4	**2.7**		Weak (slope+elevation)	No literature found
12	Landcover	2	**2.1**		Strong	(Bennitt et al., 2019, 2017; Crego et al., 2020; Hopcraft et al., 2012; Matawa et al., 2012; Sianga et al., 2017)
13	Slope	0.7	**1.1**	Ruggedness_3000 (0.77)	Weak	(Matawa et al., 2012)
14	Distance to livestock	1	**0.5**		Weak	(Ogutu et al., 2016)
11	Distance to built-up	2.4	**2.7**	Distance to roads (0.57)	Weak	(Ogutu et al., 2016)
	Landform	3.9			N/A	(Matawa et al., 2012; Weel et al., 2015)
	NDVI	1.1		Distance to open forests (-0.59), Distance to closed+open forests (-0.62), NDVI_3000 (0.93)	Strong	(Bennitt et al., 2019, 2017, 2015; Crego et al., 2020; Hopcraft et al., 2012; Matawa et al., 2012; Sianga et al., 2017)
	Ruggedness_3000	0.8		Slope (0.77)		No literature found
	Wetness	0.7			Strong	(Bennitt et al., 2015; Crego et al., 2020; Fullman et al., 2017; Hopcraft et al., 2012; Sianga et al., 2017)
	Distance to closed+open forests	0.4		Distance to closed forest (0.59), Distance to open forests (0.98), NDVI (-0.58), NDVI_3000 (-0.62)		(Bennitt et al., 2019, 2017, 2015; Crego et al., 2020; Hopcraft et al.,

						2012; Matawa et al., 2012; Sianga et al., 2017)
	Seasonal precipitation	0.4		Mean annual precipitation (-0.5), Elevation (-0.53)	Strong (rainfall)	(Bennitt et al., 2015; Hopcraft et al., 2012; Hughes et al., 2017; Naidoo et al., 2012; Ogutu et al., 2016)
	Mean temperature of the coldest quartile	0.2		Elevation (-0.96), Mean temperature of the warmest quarter (0.98), Mean annual temperature (0.99)		No literature found
	Mean annual temperature	0.1		Elevation (-0.98), Mean temperature of the coldest quarter (0.99)		No literature found
	Mean temperature of the warmest quartile	0		Elevation (-0.98), Mean temperature of the coldest quarter (0..98)	Strong (drought)	Ogutu et al, 2016

Table 8: Variables used for modelling suitable habitats for Giraffe. Details of the percentage contribution from model, multicollinearity tests and the significance of variables based on literature are compiled below. The rows are ordered by the final percent contribution (highest to lowest) and the rank column represents the ranking when all variables were used. The AUC for the model with every variable and the final variable set is also presented.

Rank	Variable	Percent Contribution		Highly correlated variable(s) (correlation value)	Influence strength, from literature	Supporting literature
		Every variable	Final			
	AUC	0.755	**0.747**			
1	Distance to protected areas	17.2	**19.4**		Moderate	(Bhola et al., 2012)
2	Distance to water body	11.8	**13.5**		Strong	(Ogutu et al., 2014; Young et al., 2020)
3	Slope	10.1	**10.8**	Ruggedness_3000 (0.77)		Not literature found
6	Distance to roads	5.6	**7.9**	Distance to built-up (0.57)		Not literature found
8	Wetness	4.8	**7.7**		Strong	(Crego et al., 2020; Ogutu et al., 2014)
4	Distance to open forest	6.5	**6.8**	Distance to closed forest (0.56), Distance to closed+open forests (0.98), NDVI (-0.55), NDVI_3000 (-0.59)		Not literature found
5	Distance to built-up	5.8	**5.9**	Distance to roads (0.57)	Moderate	(Knüsel et al., 2019; Ogutu et al., 2016)
10	Ruggedness_3000	3.5	**4.2**	Slope (0.77)		Not literature found
13	Elevation	1.6	**4**	Seasonal precipitation (-0.53), Mean temperature of the coldest quarter (-0.96), Mean temperature of the warmest quarter (-0.98), Mean annual temperature (-0.98)		Not literature found
7	Seasonal precipitation	5.4	**3.3**	Mean annual precipitation (-0.5), Elevation (-0.53)	Strong	Not literature found
16	Landcover	0.9	**2.7**		Strong	(Ogutu et al., 2016)
12	Nightlights mean_3000	2.8	**2.5**			Not literature found
11	Mean temperature of the warmest quartile	3.3	**2.3**	Elevation (-0.98), Mean temperature of the coldest quarter (0.98)	Strong (drought)	(Ogutu et al., 2016)
14	Distance to closed forest	1.4	**1.5**	Distance to open forests (0.56), Distance to closed+open forests (0.59)		Not literature found
15	Distance to livestock	1	**1**		Moderate	(Ogutu et al., 2016)
9	NDVI_3000	3.6		Distance to open forests (-0.59), Distance to closed+open forests (-0.62), NDVI (0.93)	Strong	(Brown and Bolger, 2020)
	NDVI	4.8		Distance to open forests (-0.59), Distance to closed+open forests (-0.62), NDVI_3000 (0.93)	Strong	(Brown and Bolger, 2020)
	Distance to closed+open forests	4.2		Distance to closed forest (0.59), Distance to open forests (0.98), NDVI (-0.58) NDVI_3000 (-0.62)		Not literature found
	Mean annual precipitation	2.8		Seasonal precipitation (-0.5)	Strong (rainfall)	(Bennitt et al., 2015; Knüsel et al., 2019; Ogutu et al., 2016, 2014; Watson and Chadwick, 2007)
	Mean annual temperature	1		Elevation (-0.98), Mean temperature of the coldest quarter (0.99)	Applies to drought only	(Ogutu et al., 2016)
	Landform	0.9				Not literature found
	Mean temperature of the coldest quartile	0.5		Elevation (-0.96), Mean temperature of the warmest quarter (0.98), Mean annual temperature (0.99)	Applies to drought only	(Ogutu et al., 2016)
	Landform_3000	0.4				Not literature found

Table 9: Variables used for modelling suitable habitats for Zebra. Details of the percentage contribution from model, multicollinearity tests and the significance of variables based on literature are compiled below. The rows are ordered by the final percent contribution (highest to lowest) and the rank column represents the ranking when all variables were used. The AUC for the model with every variable and the final variable set is also presented.

Rank	Variable	Percent Contribution		Highly correlated variable(s) (correlation value)	Influence strength, from literature	Supporting literature
		Every variable	Final			
	AUC	0.778	**0.77**			
1	Mean temperature of the warmest quartile	13.3	**17**	Elevation (-0.98), Mean temperature of the coldest quarter (0.98)	Weak	(Weel et al., 2015)
3	Distance to protected areas	11.6	**14.9**		Strong	(Ogutu et al., 2016)
4	Distance to livestock	11.1	**13.3**			No literature found
5	Elevation	10.7	**11.4**	Seasonal precipitation (-0.53), Mean temperature of the coldest quarter (-0.96), Mean temperature of the warmest quarter (-0.98), Mean annual temperature (-0.98)	Strong (rainfall)	(Bennitt et al., 2015; Ogutu et al., 2014; Ogutu and Owen-Smith, 2005; Owen-Smith and Mills, 2006; Watson and Chadwick, 2007)
6	Mean temperature of the coldest quartile	9.6	**10.4**	Elevation (-0.96), Mean temperature of the warmest quarter (0.98), Mean annual temperature (0.99)	Applies to drought only	(Ogutu et al., 2016)
7	Distance to water body	5.9	**6.5**		Strong	(Bennitt et al., 2019; Crego et al., 2020; Novellie and Winkler, 1993)
8	NDVI_4000	4.5	**6.4**	Distance to closed+open forests (-0.62), NDVI (0.93)	Strong	(Bhola et al., 2012)
2	Ruggedness_4000	12.5	**6.1**	Slope (0.75)		No literature found
9	Wetness	3.4	**4.4**		Weak (slope+elevation)	No literature found
10	Mean annual precipitation	3.3	**2.2**	Seasonal precipitation (-0.5)	Strong	(Crego et al., 2020; Young et al., 2020)
11	Distance to closed+open forests	2.2	**2.2**	Distance to closed forest (0.59), NDVI (-0.59), NDVI_4000 (-0.62)	Moderate	Ogutu et al, 2016
13	Nightlights mean_4000	1.2	**2.1**		Strong	(Crego et al., 2020; Novellie and Winkler, 1993)
12	Distance to built-up	1.7	**1.8**	Distance to roads (0.57)	Not found	No literature found
14	Landcover	0.6	**1**		Not found	
15	Landform	0.6	**0.4**		Not found	No literature found
	Distance to closed forest	1.9		Distance to closed+open forests (0.59)	Not found	No literature found
	NDVI	1.9		Distance to closed+open forests (-0.58), NDVI_4000 (0.93)	unknown	(Bennitt et al., 2019; Ogutu and Owen-Smith, 2005)
	Slope	1.4		Ruggedness_4000 (0.75)	Applies to drought only	(Ogutu et al., 2016)
	Distance to open forest	1			Not found	No literature found
	Distance to roads	0.5		Distance to built-up (0.57)	Not found	No literature found
	Seasonal precipitation	0.5		Mean annual precipitation (-0.5), Elevation (-0.53)	Strong (NDVI)	No literature found
	Mean annual temperature	0.4		Elevation (-0.98), Mean temperature of the coldest quarter (0.99)	Strong (rainfall)	(Bennitt et al., 2015; Ogutu et al., 2014; Owen-Smith and Mills, 2006; Watson and Chadwick, 2007)
	Landform_4000	0.1			Not found	No literature found

2.5.4. MaxEnt Modelling

Using the filtered occurrence points, the bias file and the final set of explanatory variables for each species as inputs into MaxEnt we modelled habitat suitability. The quality of the outputs obtained were assessed using the Area Under the Curve (AUC) which has emerged as the most popular way of testing model performance in the MaxEnt literature (Merow et al., 2013). Models with AUC values above 0.75 are often considered potentially useful (Elith et al., 2006), however, Merow et al. (2013) cautioned against using thresholds .

Maxent was ran with 10 replicates to test model performance by measuring the amount of variability in the model (Young et al., 2011) and with cross-validation, is important for making better use of small data sets and to describe average AUC across models, and summary response curves with one standard deviation error bars (Phillips, 2017). The model was set to 5000 iterations with a convergence threshold of 0.00001 to have adequate time for convergence. If the model doesn't have enough time to converge, the model may over-predict or under-predict the relationships. (Young et al., 2011).

The outputs from the MaxEnt modelling are raster surfaces described by a habitat suitability index (HSI) with values ranging from 0 to 1. Where 0 represent unsuitable areas and 1 represent very suitability areas.

2.6. Connectivity modelling

2.6.1. Transforming habitat suitability into resistance surface and habitat patches

For the connectivity modelling, the only data inputs required were the resulting habitat suitability maps from the MaxEnt modelling in the previous step. These maps were converted into a resistance surface and into habitat patches using the following negative exponential function (Bourdouxhe et al., 2020; Duflot et al., 2018):

If HSI > threshold; species habitat and resistance = *no resistance*

If HSI < threshold; non-habitat/matrix, resistance = $e^{\frac{ln(0.001)}{threshold}} \times max\, resistance$

Equation 1

Where the max resistance was assignment to be 300%.

This function assigns a resistance value of 300% when HSI = 0, and no resistance when HSI is greater than or equal to the habitat threshold. The HSI threshold was based on the Equal Test sensitivity and specificity logistic threshold (Kramer-Schadt et al., 2013; Mellick et al., 2013). Sensitivity specificity equality threshold approaches have been demonstrated to have reasonable statistical properties (Liu et al., 2005). Furthermore, this threshold was supported by a qualitative assessment of area with known populations identified by experts.

2.6.2. Modelling connectivity with Graphab

To characterise least-cost paths between patches and the importance of the patches and linkages between these patches, the software Graphab was used (Foltête et al., 2021, 2012). Least-costs paths represent species movement pathways between two patches which have the minimum cumulative cost distance. The cumulative cost distance describes the accumulated travel cost from one location to another based on a resistance surface rather than actual distance (i.e. Euclidian distance).

The location and extent of a patch was defined by the HSI threshold, as described above, where the patches were above a minimum patch size as defined in Table 4. The patch size threshold represents the smallest value of average minimum values for the Buffalo and Giraffe and maximum value of overall minimum for Zebra. These values were chosen so as to identify patches sizes which represent the average smallest patch values while ignoring outliers.

Least-cost paths were identified where the cumulative cost-distance was less than the interpatch dispersal distance threshold. If the total cost of traversing the distance between the two patches exceeds the interpatch dispersal distance threshold, no least-cost path will be produced.

To quantify connectivity across the study area, we visualised which patches were isolated and characterised the importance of patches and linkages between patches using graph metrics. Isolation can be described by component boundaries which represent a group of patches of habitat for a particular species or group of species that are linked to each other but isolated from other components. The spatial patterns of these components were analysed in order to identify regions which are highly fragmented and made up of numerous groups or single isolated patches (Lechner et al., 2015). In contrast, areas with large components made up of many patches represent well-connected regions. We calculated one patch/link-scale metric and seven landscape-scale metrics. The patch-scale graph metric delta Integral index of connectivity (dIIC) (Pascual-Hortal and Saura, 2006; Saura and Pascual-Hortal, 2007) was used to represent the importance of a linkage or patch for connecting the landscape. dIIC expresses the change in habitat availability caused by the elimination of the focal patch. A higher dIIC value denotes that a linkage or patch is important for connecting habitat in the study area.

The seven landscape scale graph metrics were: Mean size of components (ha); Size of largest component (ha); Number of components; Integral index of connectivity (IIC); Number of Links; Number of Patches; Size of largest patch (ha); and Total patch area (ha). The IIC describes how connected habitat is within a landscape (Pascual-Hortal and Saura, 2006; Saura and Pascual-Hortal, 2007). The IIC metric is defined as the probability that two points randomly placed within a landscape fall into habitat areas that can be reached.

2.6.3. Additional connectivity modelling in the RAA with Linkage Mapper and Circuitscape

For the RAA we conducted additional analyses using Linkage Mapper which includes Circuitscape. Using Linkage Mapper we characterised least-cost corridors and within those corridors characterised probability of movement. Least-cost corridors are defined as a corridor between two patches where its width is limited by the cost-weighted distance threshold defined by the resistance surface and interpatch dispersal distance threshold. Areas not within the least-cost corridors represent parts of the matrix which are not utilised for movement. For some species the whole of the matrix can be potentially used for movement and thus the whole study area is represented within these corridors. While for other species with restricted movement only a small component of the matrix will be found within the least-cost corridor.

Within the least-cost corridors Circuitscape was used to characterise probability of movement based on random walk patterns modelled using circuit theory. Circuitscape uses current density, analogous to electrical current, as a proxy for movement probability. High current density values indicate areas which have higher movement probability and vice versa. Pinch-points (or choke-points) are areas where fauna movement is constrained and funnelled and represents areas where the loss of a single linkage will cause significant reductions in landscape connectivity (McRae et al. 2008). These locations will often overlap with the least-cost path, providing an indication of whether a least-cost path has low redundancy. Areas with high current density should be considered as priority for conservation.

We ran two scenarios for the RAA: (i) a default and (ii) favourable movement scenario. The first scenario was with the Default parameterisation (Table 4) which was also used for the CAA. For the favourable movement scenario habitat patch size is 5% of the original value and the interpatch dispersal distance threshold is doubled. The favourable movement scenario is used to characterise movement between patches of habitat which are not considered core as they are smaller in size (i.e. 5% of the original size) and for animals that can travel twice as far. This approach is essentially a test of the sensitivity of our analysis to the parameter values.

2.7. Assessment of wildlife crossings

In the final step of the analysis, we assessed the importance of 15 pre-selected wildlife crossing locations for each of the conservation targets and combined. We used the centroid of the wildlife crossing locations and overlayed those points with the Circuitscape outputs and also the dIIC values for linkages. The Circuitscape values were normalised based on the maximum current density value to derive a Movement probability index.

3.0 Results: Contextual Assessment Area

3.1. Habitat suitability mapping

Figure 10 presents maps describing the distribution of habitat suitability values for each of the three species. Higher habitat suitability values can be interpreted location where populations are more likely to be found; areas with habitat which can support a viable population over ecological timescales. These areas are likely to support foraging, breeding and movement.

All habitat suitability outputs had similar patterns, with higher habitat suitability in the northeast and the south, and large swaths of low habitat suitability areas fragmenting the region. Habitat suitability for the Giraffe and Zebra near the proposed highway appear relatively high in comparison to areas in the northeast and south, unlike for the buffalo. More maps comparing habitat suitability to other features such as protected areas can be found in Appendix G.

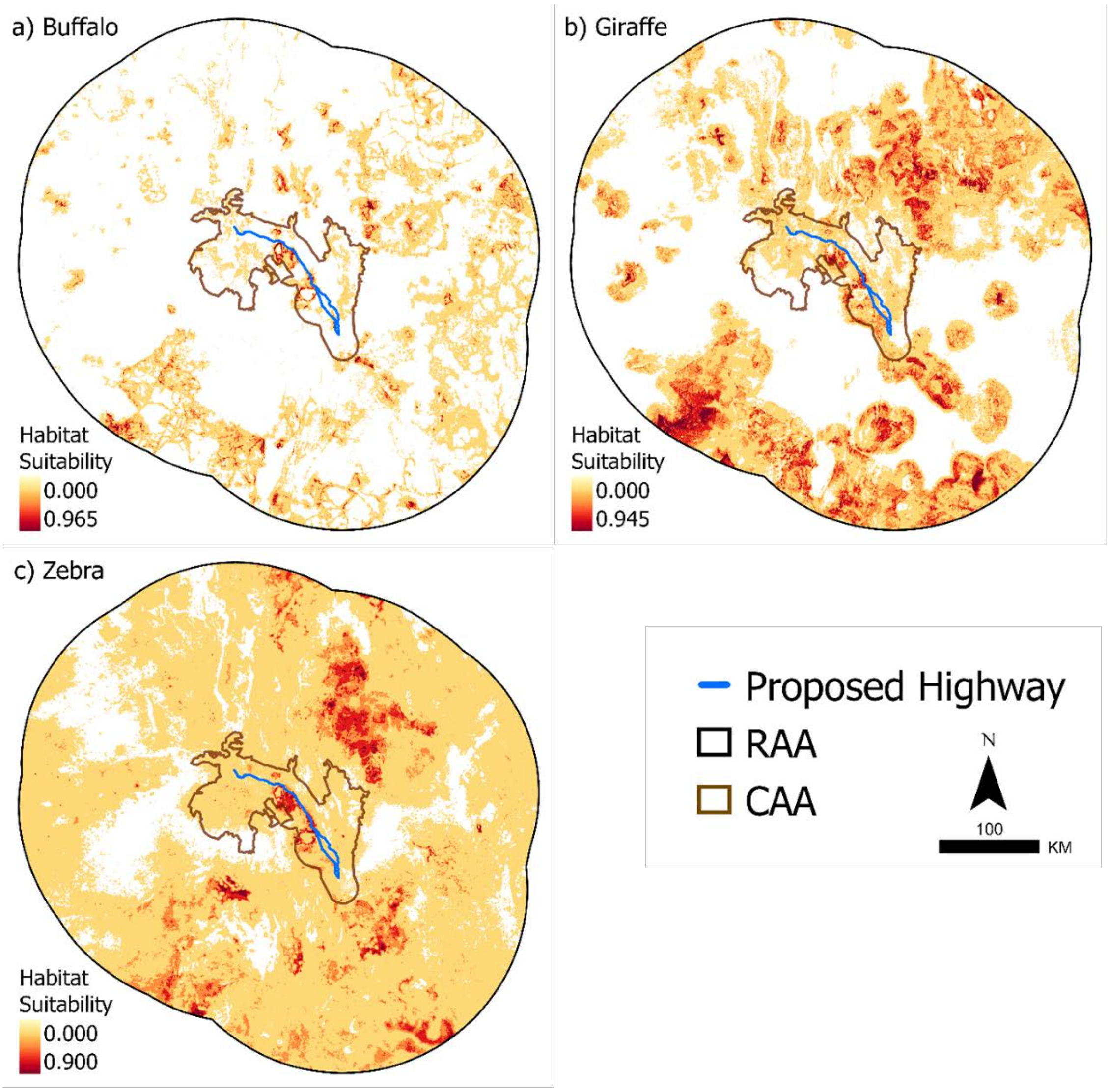

Figure 10: The MaxEnt species distribution modelling habitat suitability outputs for: (a) Buffalo, (b) Giraffe and (c) Zebra. The red pixels with higher values indicate areas with the highest suitability and white with the lowest value have the lowest suitability.

The MaxEnt habitat suitability modelling obtained satisfactory results for the three species. The AUC values were all 0.75 or greater (Table 10). The thresholds for defining habitat using the Equal Test sensitivity and specificity logistic threshold ranged from 0.2018 to 0.4337 (Table 10). The receiver operating characteristic (ROC) curves are described in Appendix H. Key contributing variables commonly identified for all three species include distance to protected areas, distance to roads and distance to forest (Table 7, Table 8 and Table 9).

Table 10: Summary of AUC values for assessing model performance and habitat Equal Test sensitivity and specificity logistic threshold.

	Buffalo	Giraffe	Zebra
AUC	0.87	0.75	0.77
Habitat Suitability Index (HSI) Threshold: Equal test sensitivity and specificity logistic threshold	0.2018	0.3734	0.4337

The final habitat suitability modelling methods were improved through sharing the preliminary outputs with local experts using the web-based expert survey. Through this process we were able identify qualitatively where the habitat suitability mapping worked or didn't work well based on the location of known populations. We also compared our outputs to the Wildlife Migratory Corridors and Dispersal Areas report (Ojwang' et al., 2017) and found similar patterns even in areas locations where we had very few occurrence datasets (i.e. in the Kenya's South).

3.2. Connectivity

The CAA connectivity outputs for the Buffalo (Figure 11), Giraffe (Figure 12) and Zebra (Figure 13) describe the locations considered as habitat patches (as they are above the HSI threshold listed in Table 10) and which patches were connected, providing an understanding of the influence from habitat outside of the RAA. Habitat patches represent core locations where populations are likely to persist. However, it is likely that populations would utilise locations outside of these patches, such as for movement/migration. The component boundaries describe the boundary between patches which are connected to each other but isolated from other sets of interlinked patches. These boundaries represent significant barriers to long-term connectivity across the CAA.

The component boundaries identified in the CAA analysis showed that the RAA is likely to be isolated from habitat outside of the RAA for all species. The RAA in all cases was found in a separate component, which is isolated from other components in the CAA. For all species, groups of components and large areas of habitat were found in the north and south and in the RAA. The importance of the patches and links are shown by the dIIC values. The mapping shows that the RAA includes high dIIC locations, and that the habitat in the RAA appears particularly important for the buffalo. However, for Zebra and Giraffe significant large areas of connected habitat exist outside the RAA. A significant area of core habitat missing from our CAA connectivity modelling, but picked up in the favourable movement scenario analysis for the RAA are areas of known habitat in the Aberdare ranges.

A key conclusion from the CAA mapping is that, there is likely to be very little influence from habitat outside of the RAA. Therefore, the RAA can be considered in isolation from patches outside. The importance of the CAA, along with supporting the modelling through increasing the sample size, is for understanding the context of the RAA. Key conclusions can be drawn on the total amount of habitat and connectivity into and outside of the study area. However, it is likely that there is considerable uncertainty in characterising the habitat accurately over such a large area. Thus, these CAA scale habitat patterns need to be interpreted with caution.

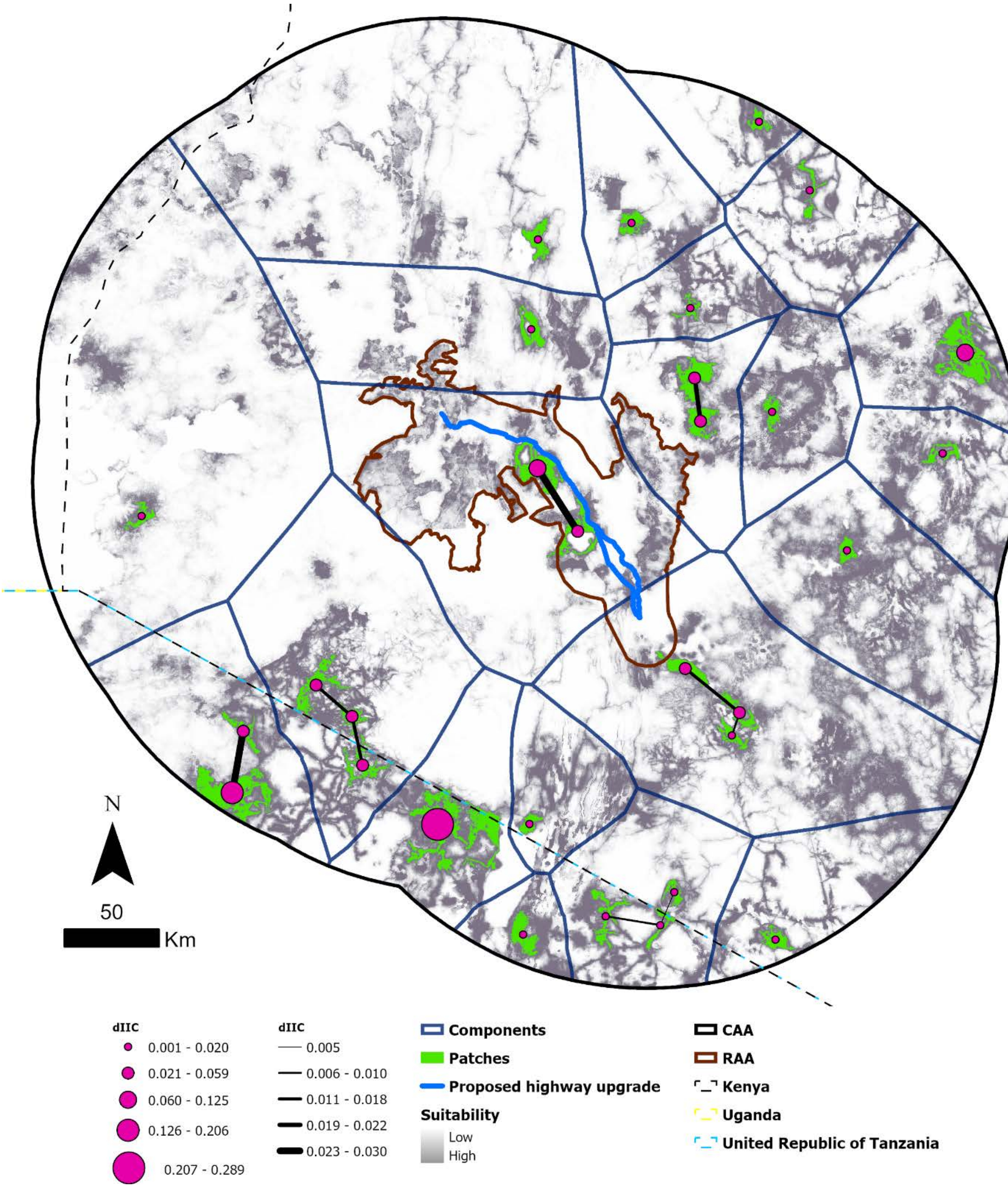

Figure 11: Buffalo habitat patches with component boundaries and delta Integral Index of Connectivity (dIIC) for patches and linkages. Important linkages and patches are denoted by thick lines and large circles respectively, and conversely thinner lines and smaller circles denote lower importance. Each component (denoted by blue lines) represents patches that are connected together but not connected to patches in other components. Least-cost paths not shown at this scale.

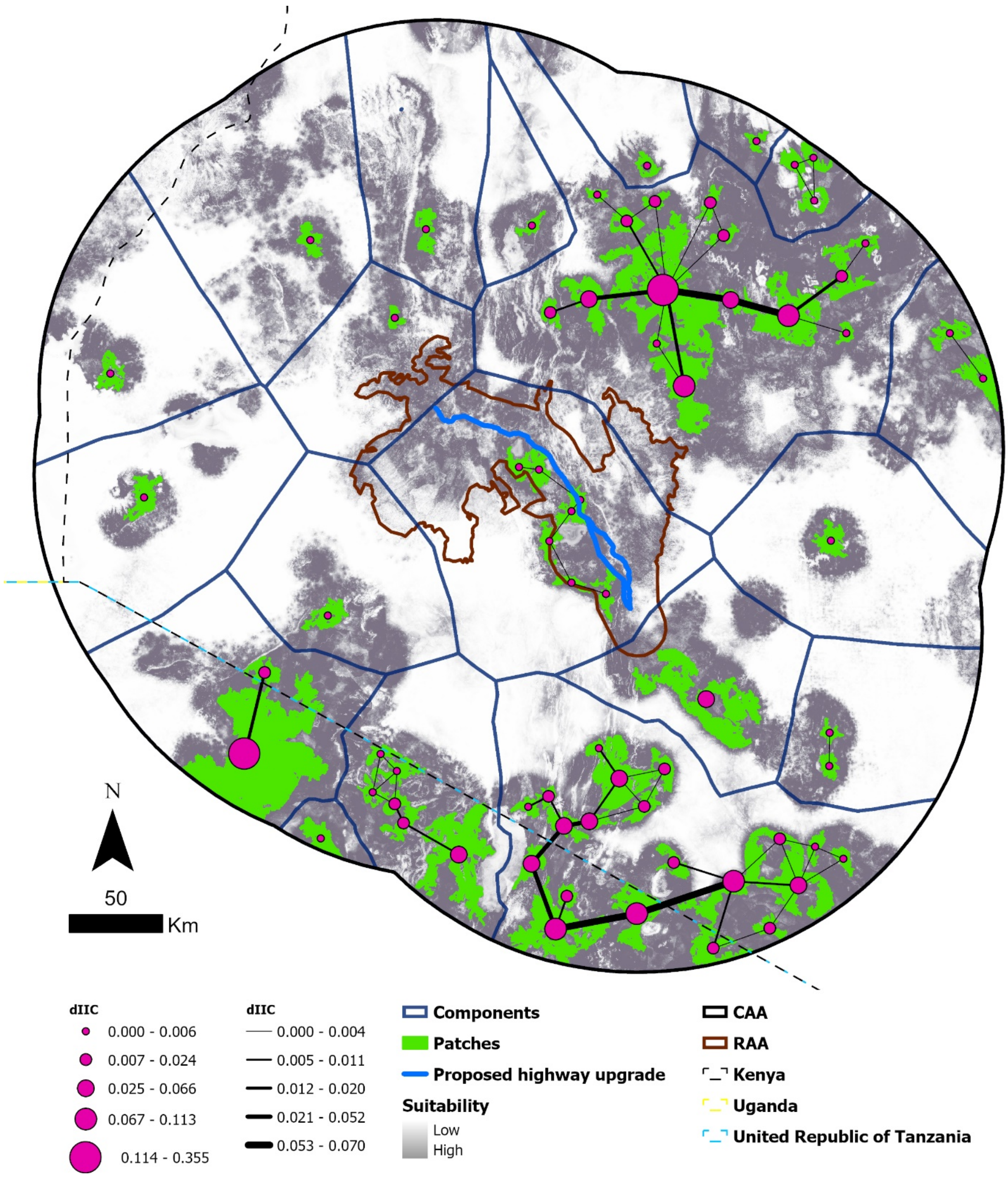

Figure 12: Giraffe habitat patches with component boundaries and delta Integral Index of Connectivity (dIIC) for patches and linkages. Important linkages and patches are denoted by thick lines and large circles respectively, and conversely thinner lines and smaller circles denote lower importance. Each component (denoted by blue lines) represents patches that are connected together but not connected to patches in other components. Least-cost paths not shown at this scale.

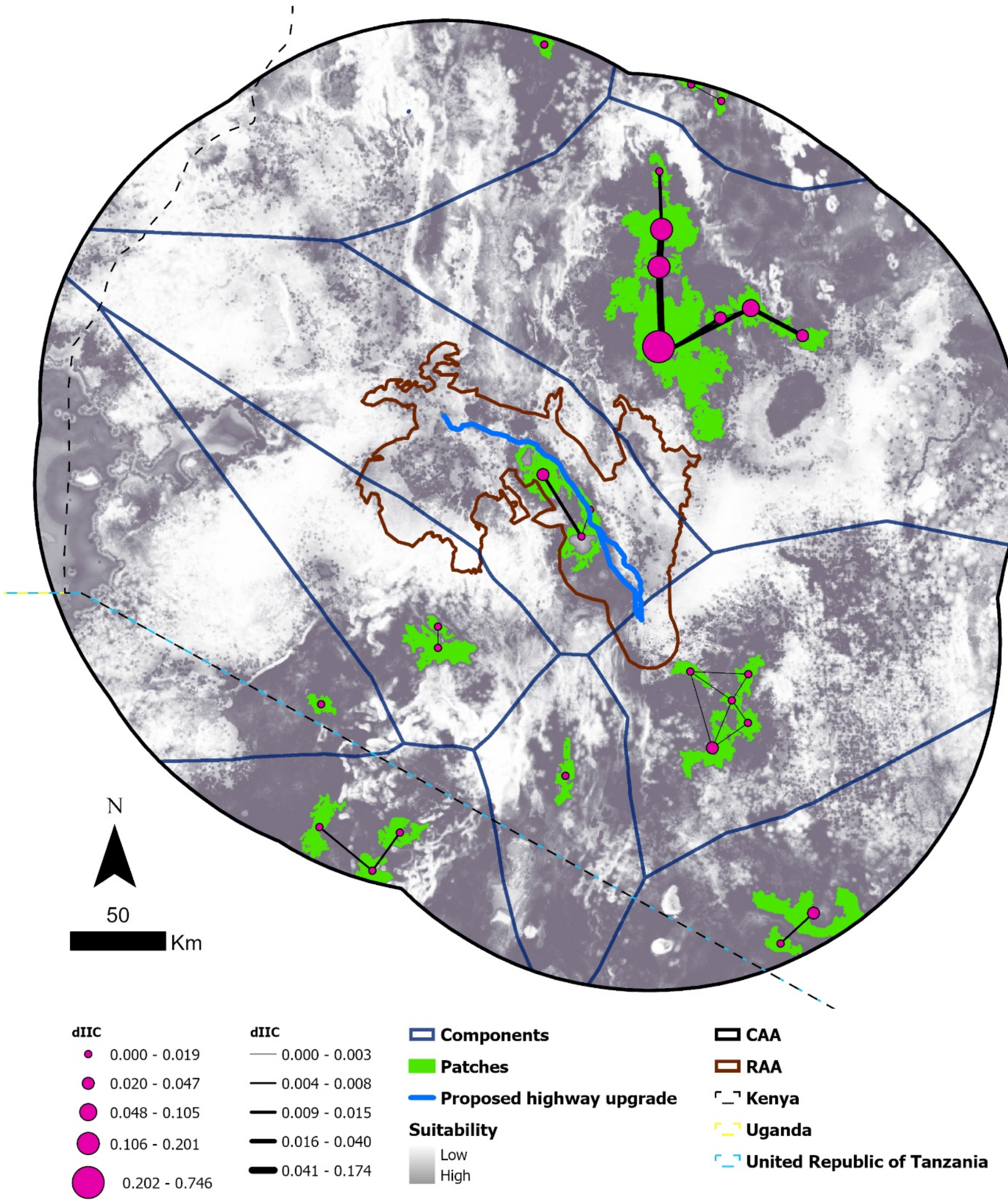

Figure 13: Zebra habitat patches with component boundaries and delta Integral Index of Connectivity (dIIC) for patches and linkages. Important linkages and patches are denoted by thick lines and large circles respectively, and conversely thinner lines and smaller circles denote lower importance. Each component (denoted by blue lines) represents patches that are connected together but not connected to patches in other components. Least-cost paths not shown at this scale.

A number of landscape-scale graph metric statistics were calculated to quantity the characteristics of the modelled habitat and connectivity (Table 11). These metrics are useful for comparing objectively between different species. Both the Giraffe and Zebra modelling outputs showed greater areas of habitat patches that were more connected than Buffalo. Overall, Giraffe had a greater total area, more patches and more links than the other species. High IIC values were observed for the Giraffe as there were few patches and many of the large patches were connected with a large number of linkages and there was a greater area of habitat overall in the landscape (i.e. IIC is defined as the probability that two points randomly placed within a landscape fall into habitat areas that can be reached). The opposite is true for the Buffalo, which has a much lower IIC value.

Table 11: Connectivity metrics for the Contextual Assessment Area (CAA) and Regional Assessment Area (RAA) analyses.

Network characteristic	Default scenario						Favourable movement scenario		
	Contextual Assessment Area			Regional Assessment Area			Regional Assessment Area		
	Buffalo	Giraffe	Zebra	Buffalo	Giraffe	Zebra	Buffalo	Giraffe	Zebra
Mean size of components (ha)	974866	1023609	2047219	655193	1307700	1292968	262077	326925	323242
Size of largest component (ha)	2899030	3112230	4811230	1179110	1307700	1292968	615444	753124	691820
Number of components	21	20	10	2	1	1	5	4	4
IIC	0.00001991	0.00029553	0.00010912	0.00013002	0.00015977	0.00026957	0.00017275	0.00022372	0.00029346
Number of linkages	9	61	21	1	6	2	16	82	12
Number of patches	30	69	27	3	7	3	17	38	13
Size of largest patch (ha)	64012	268024	191260	25904	11940	35668	25904	11940	35668
Total patch area (ha)	446456	1468580	644688	55604	61400	60820	72316	78408	66212

4.0 Results: Regional Assessment Area

4.1. Regional Assessment Area analysis overview

The RAA analysis focused on the highway upgrade and surrounding areas for the three species (Figure 14, Figure 15, Figure 16, Figure 17, Figure 18 and Figure 19). At the CAA-scale the focus was on broad-scale connectivity and the linkage between patches and the patterns of components. However, at the RAA-scale the analysis focuses on single patches and the location of the least-cost paths between these patches. Furthermore, using Linkage Mapper we can define least-cost corridors and with the Circuitscape modelling we provide a full assessment of how species use the matrix at the pixel level.

The RAA analysis for all the three species showed north-south connections parallel to the west of the highway connecting Lake Nakuru, Soysambu and Lake Elementaita in the north and an agglomeration of reserves in the south which include Marula and Naivasha Wildlife Sanctuary (hereafter referred to as the north agglomeration and the south agglomeration). These two agglomerations were consistently identified for all scenarios (default and favourable) and all species. In addition, the agglomerations were always connected via narrow strips of habitat or least-cost path, and areas of high movement probability locations located directly to the west and parallel to the highway. Furthermore, the Circuitscape analysis consistently showed that the least-cost corridor between these two agglomerations was the widest and had medium to high movement probability across the matrix.

For all species the majority of the habitat and linkages were found to the west of the highway. However, significant patches were found directly to the east of these agglomerations (i.e. Marula Estate), especially with the favourable movement scenario and especially in the south. The highway is likely to be a key barrier for fragmenting and intersecting these patches.

While the default scenarios consistently identify the north and south agglomerations, the favourable movement scenarios identify habitat in the north corresponding to the Menengai Forest Reserve and Nakuru National Park which were connected to the northern agglomeration. While in the south the Kikuyu Escarpment and Aberdare National Park and connections to the southern agglomeration were also identified though less consistently.

Our modelling showed that the patches either side of the highway are connected, for the sake of the simulation, in order to identify the most optimal locations for wildlife corridors. These connections are likely to be disrupted without the support of wildlife crossing measures. Our current modelling did not include roads as an absolute barrier to movement, which will be the case once the upgrade has been completed.

4.2. Regional Assessment Area connectivity analysis for the Buffalo

The RAA analysis of the buffalo show that it had the most limited distribution and connectivity of all the threes species (Table 11). For the default scenario only three patches were identified, of which two connected patches were responsible for the majority of the habitat area (Figure 14, Table 11). In contrast, for the favourable scenario 17 patches and 16 linkages were identified (Figure 15, Table 11). Significantly, the favourable scenario identified patches and connectivity between the Kijabe forest which includes the Kikuyu Escarpment and Aberdare National Park, although these patches were small non-core habitat (represented by patches with a patch size threshold 5% of the default). In addition, the favourable scenario identified a number of non-core patches in the east connected across the highway to the two agglomerations in the north and south. However, these patches were isolated from the two agglomerations, as shown by the component boundaries. The Circuitscape assessment showed that high movement probability areas were mostly confined to locations near the least-cost paths except toward the northwest.

4.3. Regional Assessment Area connectivity analysis for the Giraffe

The RAA analysis of the Giraffe shows that it had the largest total patch area and the most number of linkages for both default and favourable movement scenarios compared to the other two species (Table 11). For the default scenario, the Giraffe modelling identified habitat patches to the east and on the other side of the highway for the southern agglomeration and connectivity to the southern part of the study area unlike for the Buffalo and Zebra (Figure 16). The favourable movement scenario showed that the Giraffe potentially utilises a large proportion of the central and southern parts of the study area and to the west and east across the road (Figure 17), as demonstrated by the broad distribution of the least-cost corridor and medium to high movement probability values across the study area. Also, a number of patches and links were shown in the southern part of the study area which link the Escarpment/ Aberdare National Park to the southern agglomeration unlike for the other species.

4.4. Regional Assessment Area connectivity analysis for the Zebra

The Zebra had the second largest patch total area which were primarily confined to the two agglomerations for both scenarios (Table 11, Figure 18, Figure 19). Significantly, the default scenario showed that the Zebra had large areas of habitat on either side of the highway running parallel to the road (Figure 18). On the west side of the highway the north and south agglomeration was almost contiguous and separated only by a small stretch of non-habitat. The favourable movement scenario identified the habitat and connections to the Menengai/Nakuru protected areas (Figure 19). The favourable movement scenario for the Zebra showed the least amount of increase in small patches and linkages compared to the default scenario (Table 11).

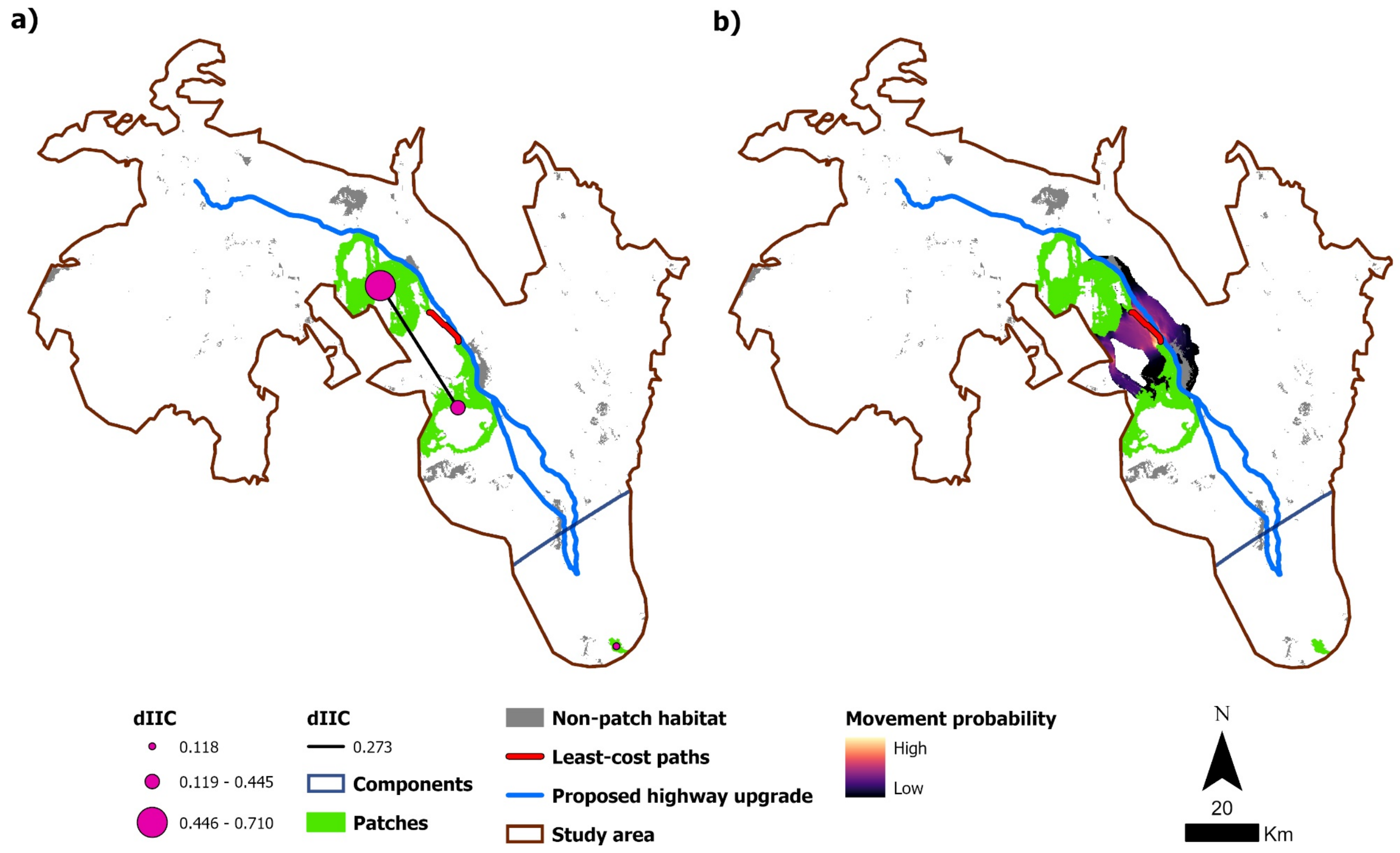

Figure 14: Buffalo default scenario with least-cost paths, component boundaries and delta Integral Index of Connectivity (dIIC) of patches and linkages for: a) graph analysis and b) linkage mapper with Circuitscape. Important linkages and patches are denoted by thick lines and large circles respectively. The least cost path (red line) represents the optimal likely movement pathway between the two patches.

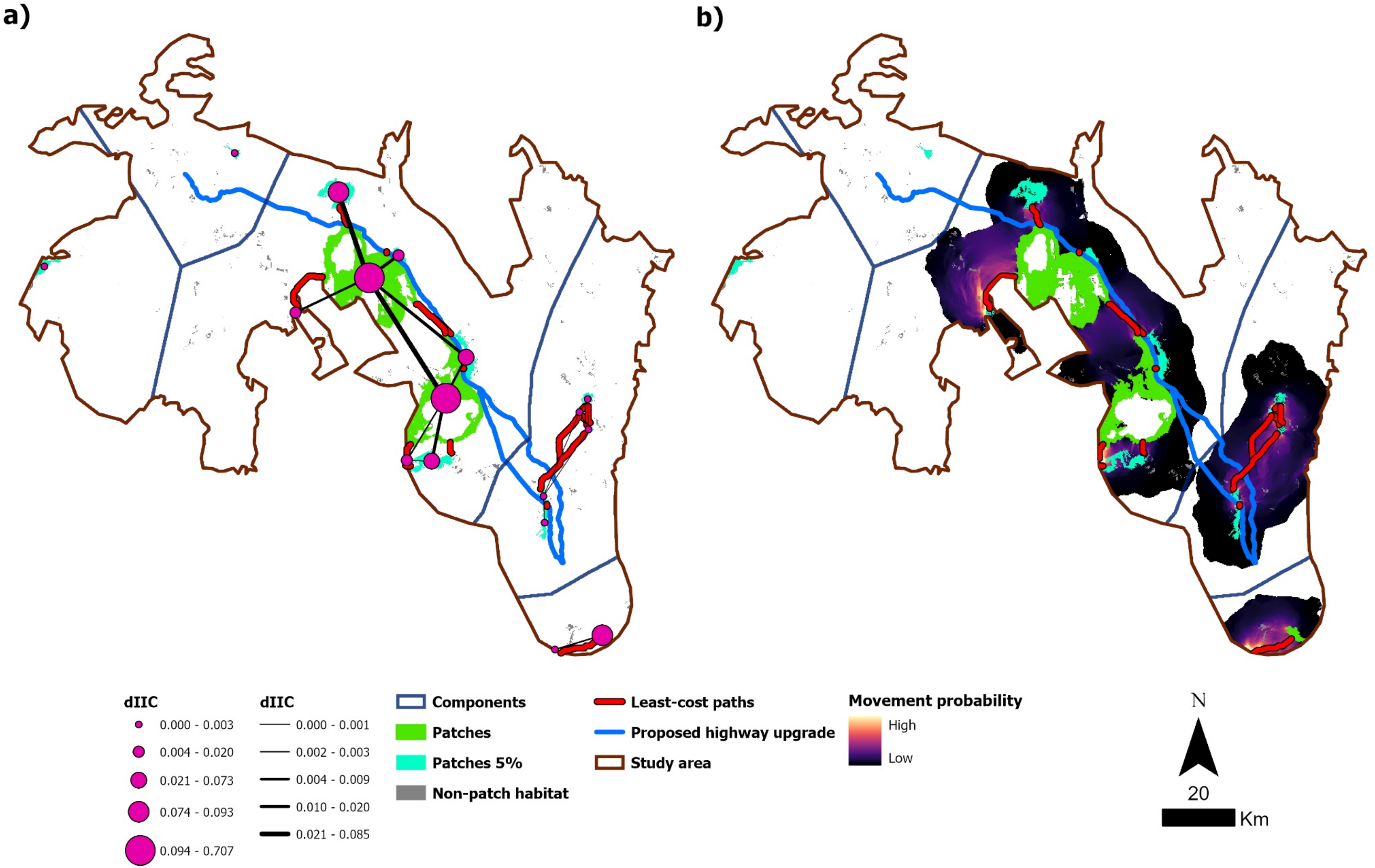

Figure 15: Buffalo favourable movement scenario with least-cost paths, component boundaries and delta Integral Index of Connectivity (dIIC) of patches and linkages for: a) graph analysis and b) linkage mapper with Circuitscape. Important linkages and patches are denoted by thick lines and large circles respectively. The least cost path (red line) represents the optimal likely movement pathway between the two patches.

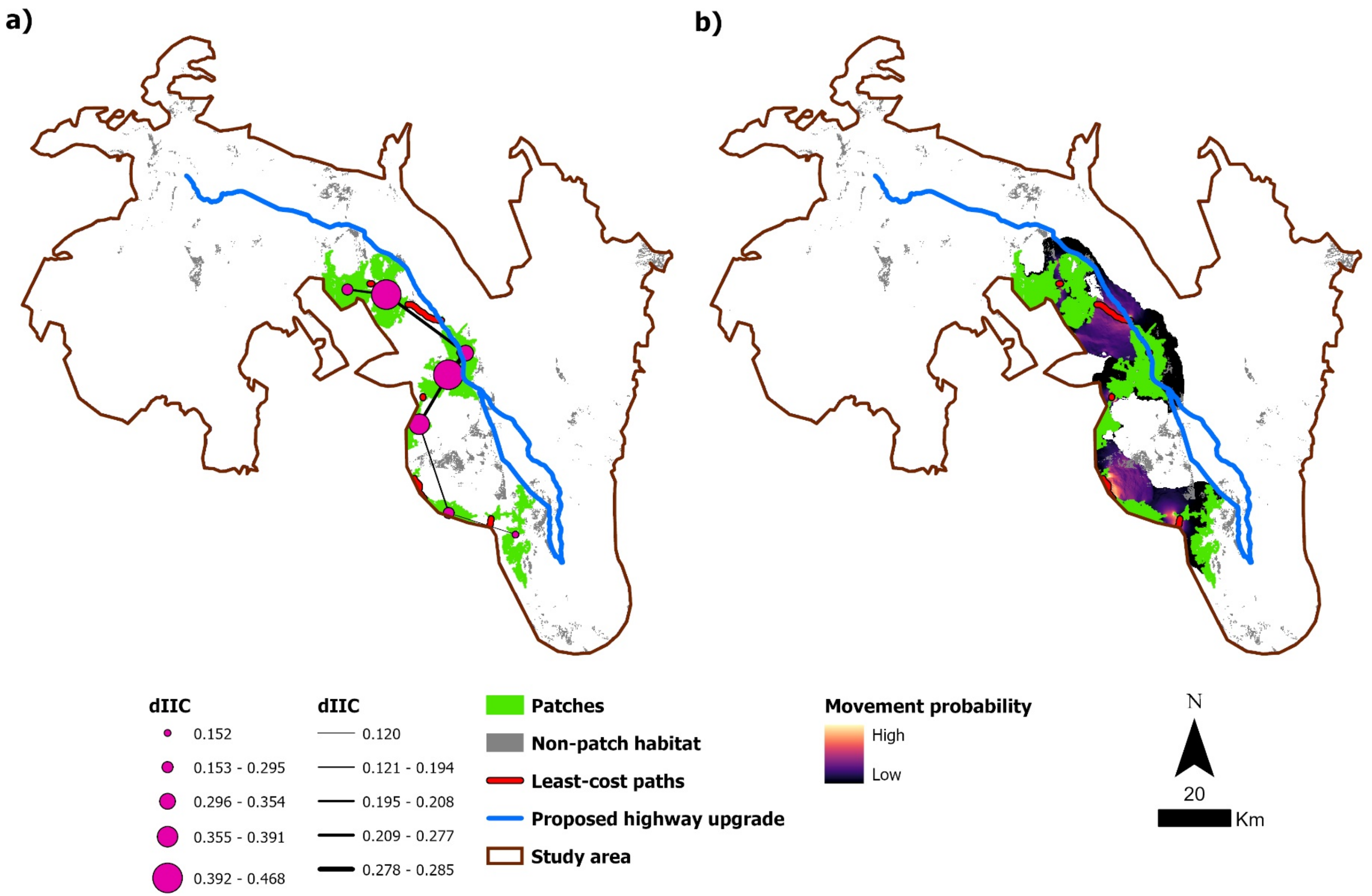

Figure 16: Giraffe default scenario with least-cost paths, component boundaries and delta Integral Index of Connectivity (dIIC) of patches and linkages for: a) graph analysis and b) linkage mapper with Circuitscape. Important linkages and patches are denoted by thick lines and large circles respectively. The least cost path (red line) represents the optimal likely movement pathway between the two patches.

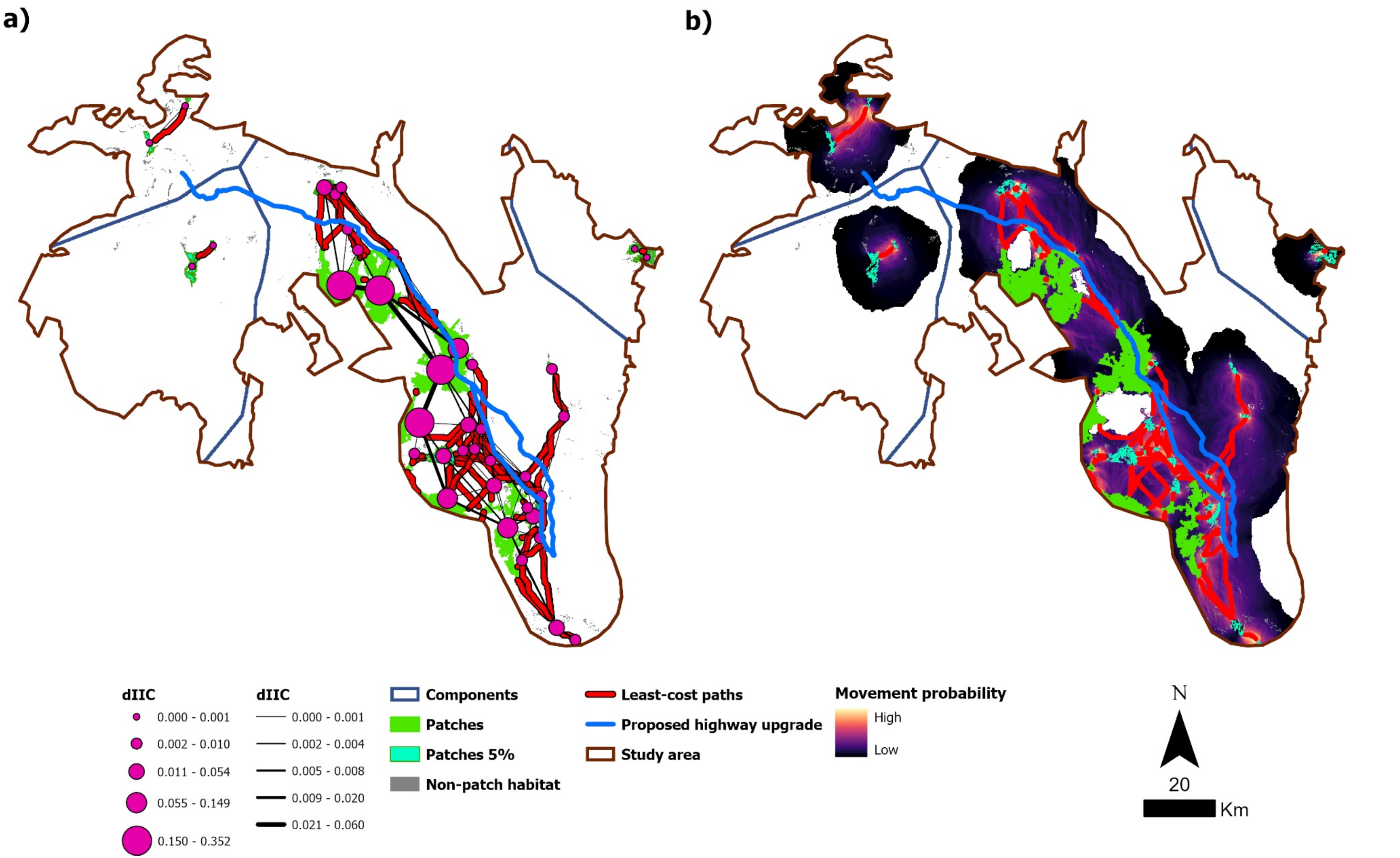

Figure 17: Giraffe favourable movement scenario with least-cost paths, component boundaries and delta Integral Index of Connectivity (dIIC) of patches and linkages for: a) graph analysis and b) linkage mapper with Circuitscape. Important linkages and patches are denoted by thick lines and large circles respectively. The least cost path (red line) represents the optimal likely movement pathway between the two patches.

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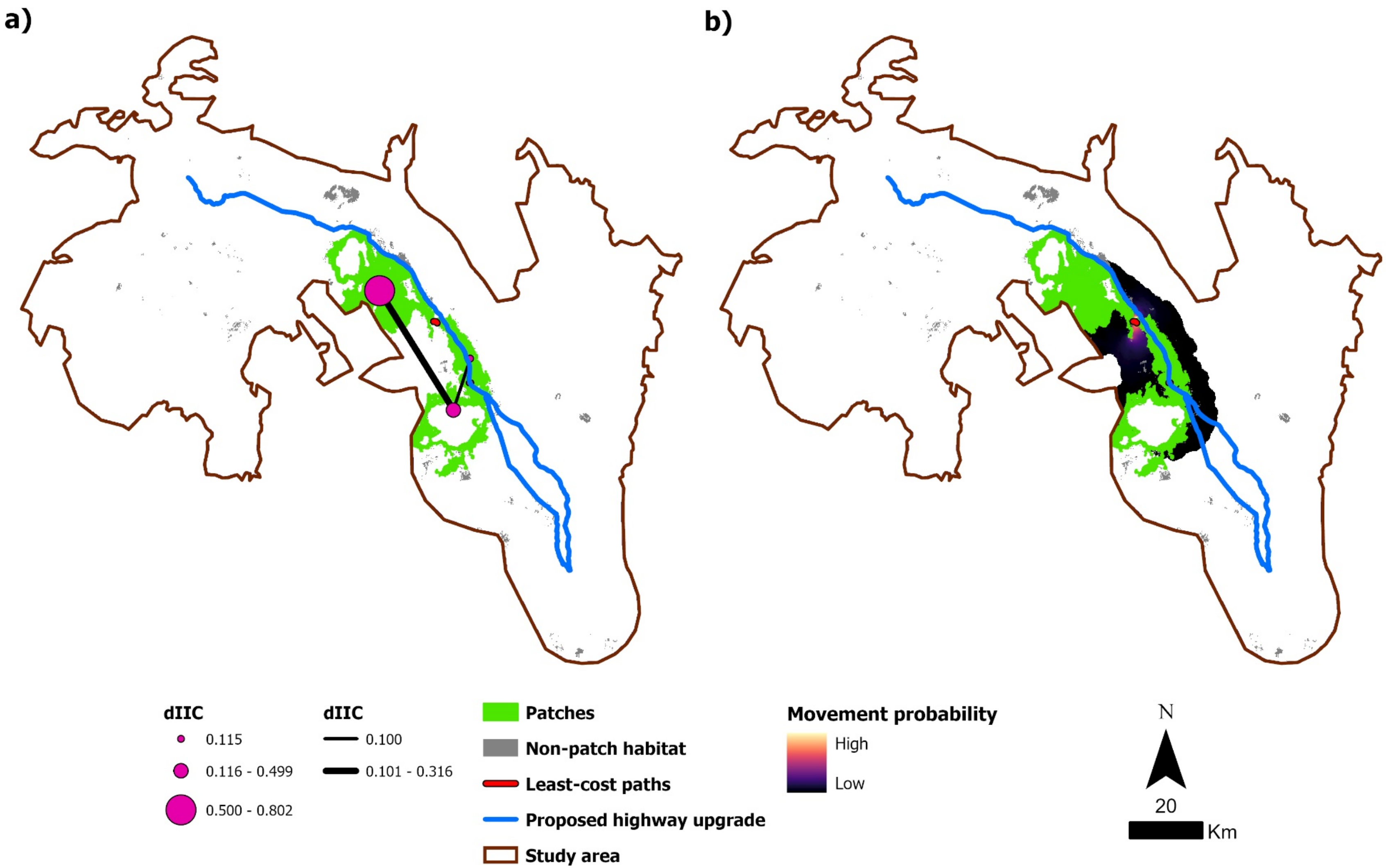

Figure 18: Zebra default scenario with least-cost paths, component boundaries and delta Integral Index of Connectivity (dIIC) of patches and linkages for: a) graph analysis and b) linkage mapper with Circuitscape. Important linkages and patches are denoted by thick lines and large circles respectively. The least cost path (red line) represents the optimal likely movement pathway between the two patches.

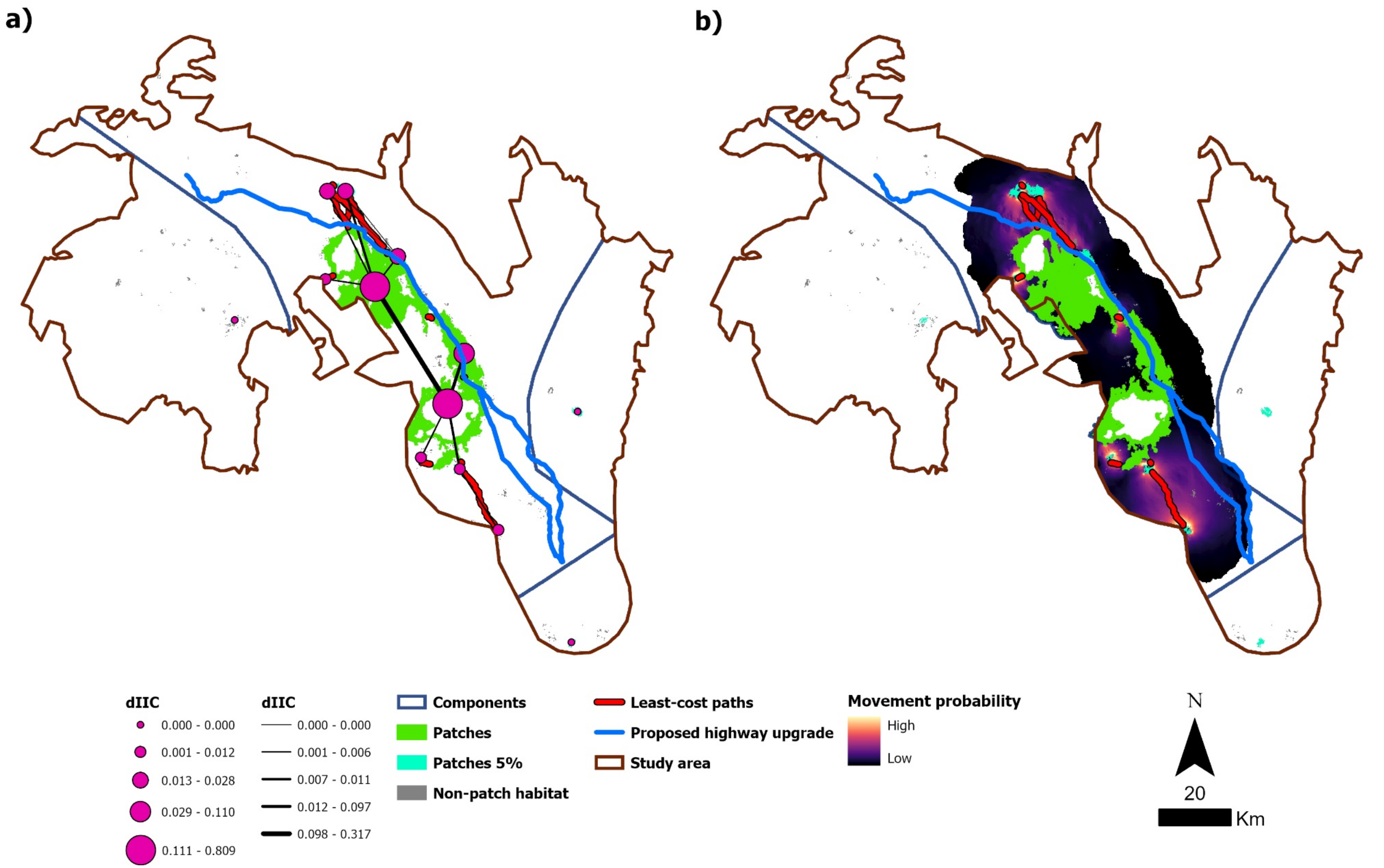

Figure 19: Zebra favourable movement scenario with least-cost paths, component boundaries and delta Integral Index of Connectivity (dIIC) of patches and linkages for: a) graph analysis and b) linkage mapper with Circuitscape. Important linkages and patches are denoted by thick lines and large circles respectively. The least cost path (red line) represents the optimal likely movement pathway between the two patches.

5.0 Results: Wildlife Crossing Assessment

5.1. Connectivity values at wildlife crossing locations

In the final step of the analysis, we overlayed the 15 proposed wildlife crossing points with the landscape-level connectivity data describing the dIIC linkages between patches and the Circuitscape analysis describing movement probability. The wildlife crossing points which have high dIIC value indicate that they are responsible for connecting the greatest area of habitat and therefore removing connections will have the greatest detriment to connectivity across the region. While the dIIC linkages are described in terms of the existence of a connection between two patches, in some cases there will be multiple alternative pathways for connecting two patches and thus multiple wildlife crossings. The movement probability index can then be used to identify which areas within a least-cost corridor are likely to support the greatest movement and therefore a good candidate for a wildlife crossing.

Figure 20 shows that the wildlife crossings with high dIIC values are very similar for the Giraffe and Zebra, with high dIIC values for wildlife crossing IDs 4,5,6 and 4,5,6,7 respectively (Table 12). These wildlife crossing are located in close proximity to locations with patches on both sides of the highway that are linked. Wildlife crossings IDs 1, 2 and 15 consistently had a dIIC value of 0, which means they are less important for the three target species.

Figure 21 shows the favourable movement scenario dIIC values for the wildlife crossing locations. There was greater variability in the dIIC values for this scenario as the combination of patches and their size, and linkages vary greatly between species. IDs 4, 5, 6, 7, 8, 11, 12, 13 and 14 had the highest dIIC value for one or more species, while ID 9, 10 and 15 consistently had a dIIC value of 0 (Table 13).

Figure 22 shows the default scenario movement probability index values for the wildlife crossing locations. ID 9 had the highest overall sum movement probability index (Table 12). While 1, 2 and 15 was not associated with any movement.

Like dIIC values (Figure 21), the movement probability index varied greatly between wildlife crossing locations (Figure 23) for the favourable movement scenario. Overall movement probability index for ID 12 and 13 were the highest while 15 was not associated with any movement.

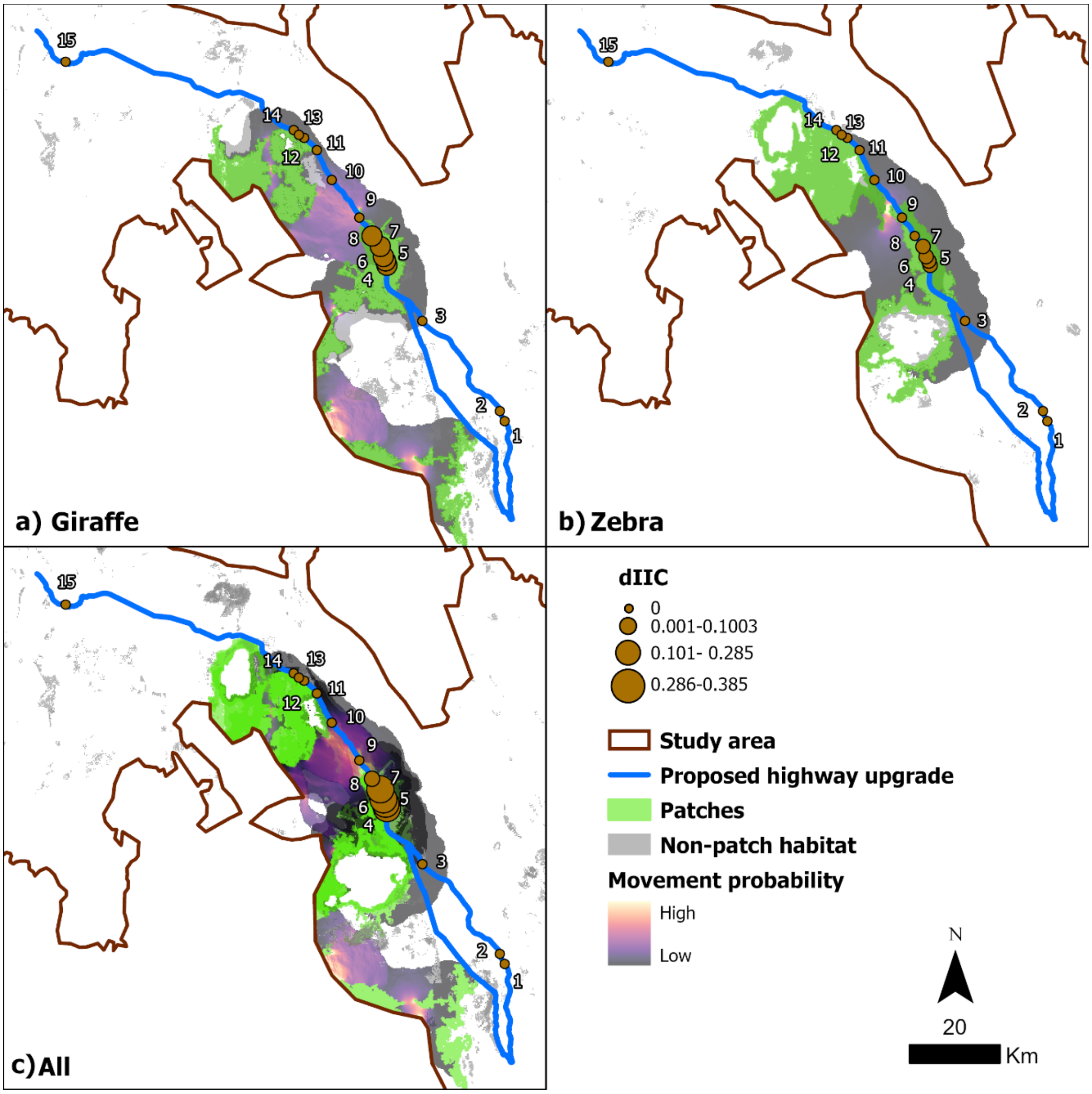

Figure 20: Default scenario dIIC of each wildlife crossing for: a) Giraffe b) Zebra c) sum of all three species. Note that buffalo was not included in the as a separate species as the dIIC values were exactly the same unlike for the favourable movement strategy.

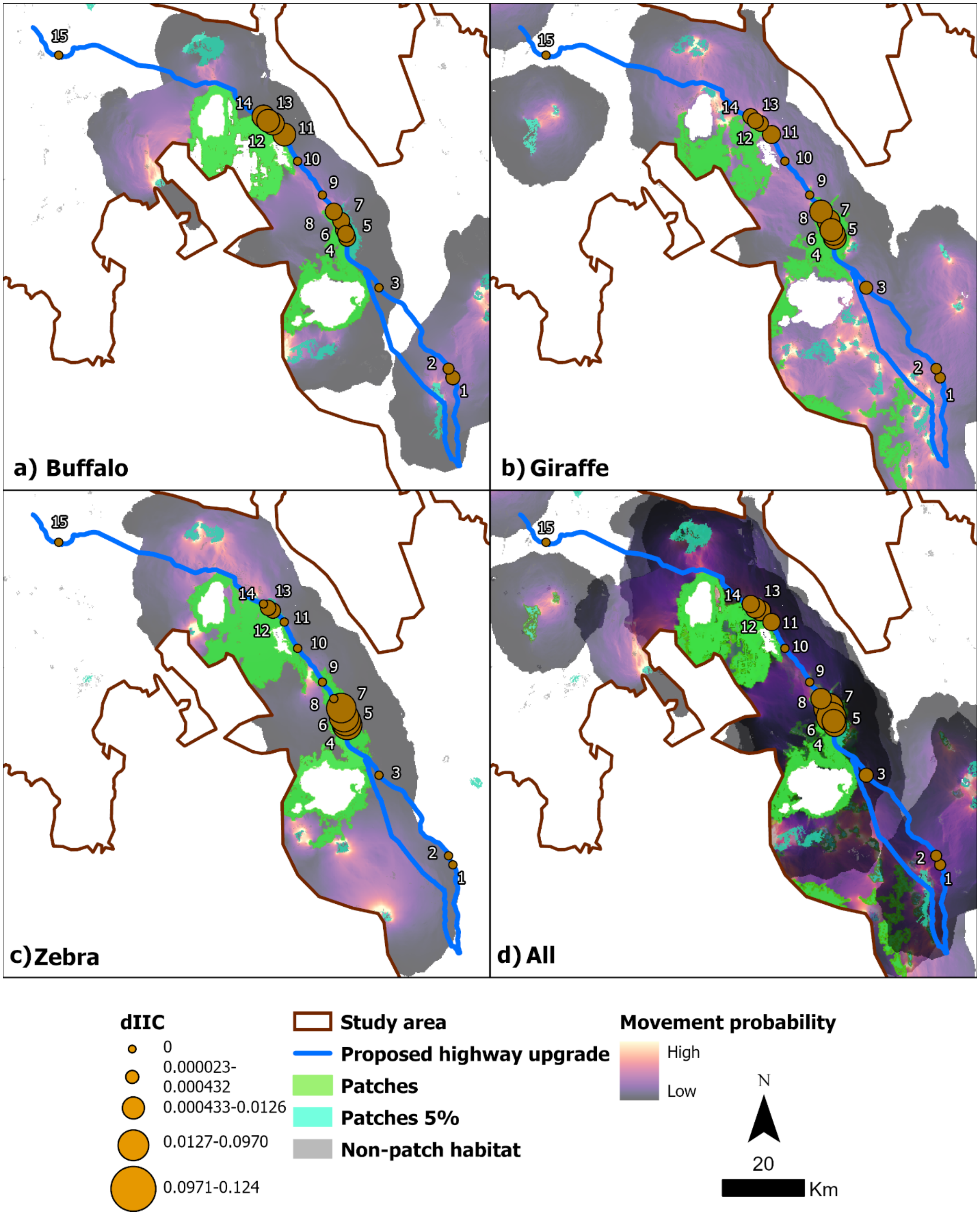

Figure 21: Favourable movement scenario dIIC of each wildlife crossing for: a) Buffalo b) Giraffe c) Zebra d) sum of all three species.

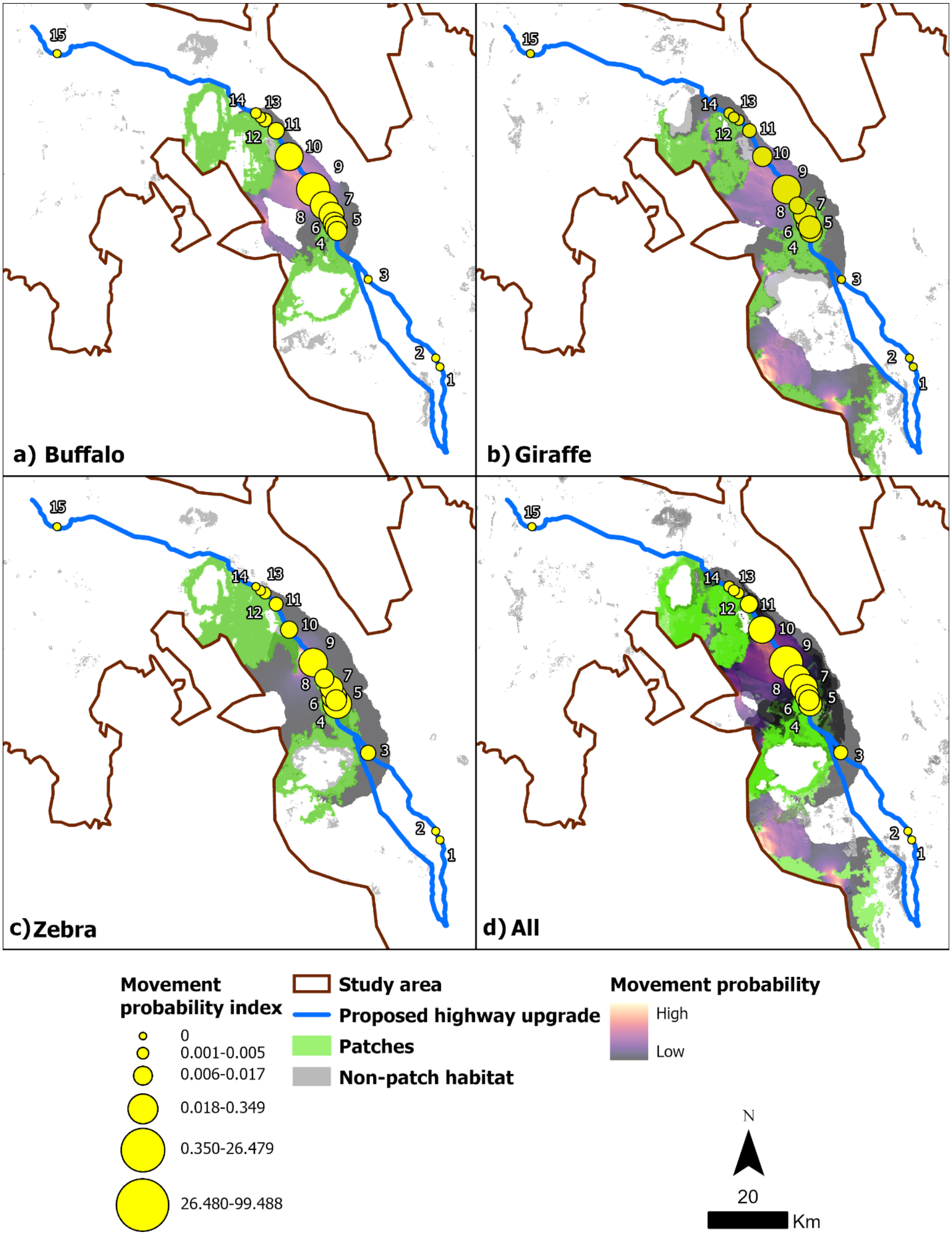

Figure 22: Default scenario movement probability index (Circuitscape) of each wildlife crossing for: a) Buffalo b) Giraffe c) Zebra d) sum of all three species.

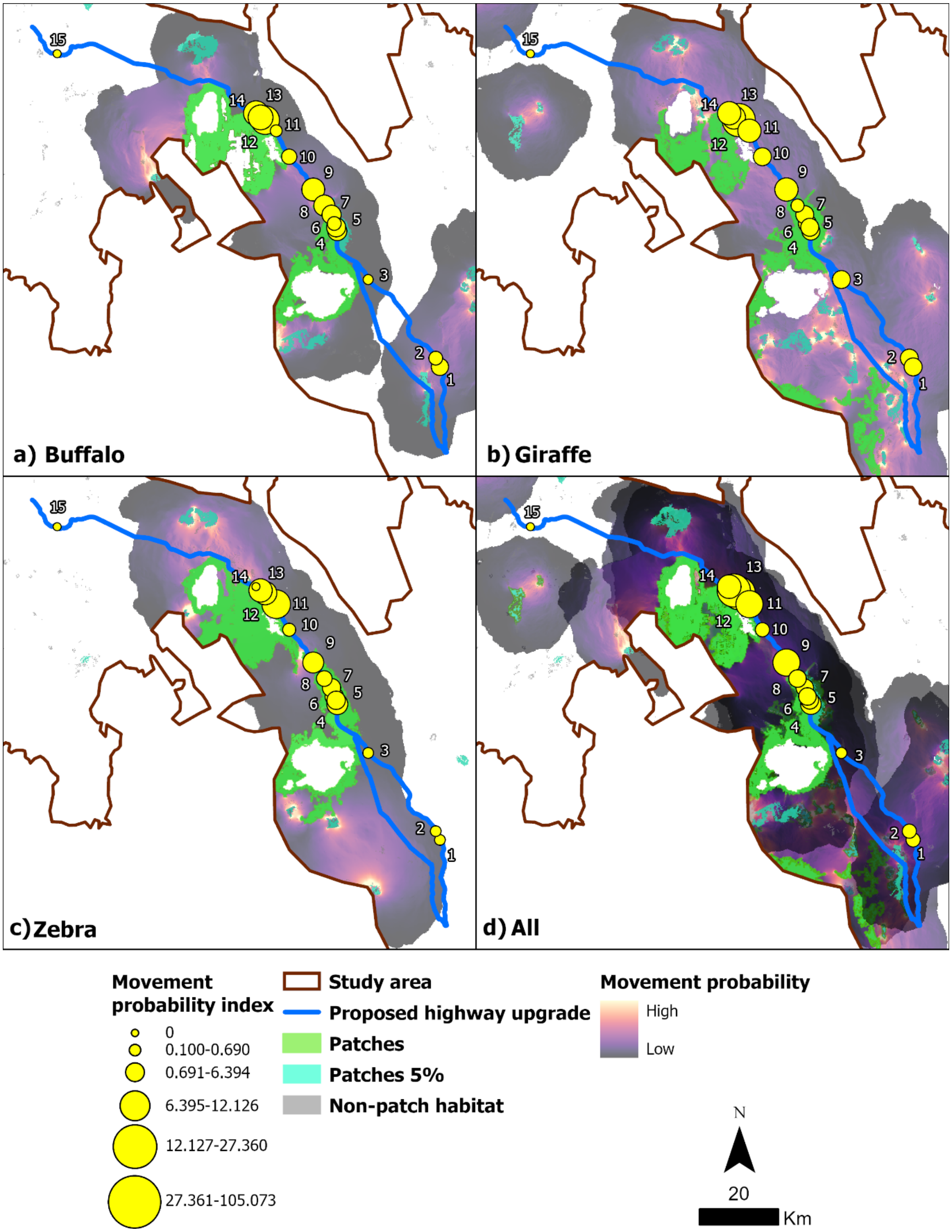

Figure 23: Favourable scenario movement probability index (Circuitscape) of each wildlife crossing for: a) Buffalo b) Giraffe c) Zebra d) sum of all three species.

Table 12: Default scenario wildlife crossing contribution to connectivity. A zero indicates that a particular wildlife crossing does not support connectivity. Values from green to red indicate important to less important wildlife crossings according to the modelling.

							Buffalo		Giraffe		Zebra		All 3 species	
ID	**Chainage**	**Construction**	**Size**	**Location**	**Description**	**Conservation management**	**dIIC**	**Movement probability index**	**dIIC**	**Movement probability index**	**dIIC**	**Movement probability index**	**Sum of dIIC**	**Sum movement probability index**
1	22+825	Underpass	1 x 5.00 x 3.50	Kijabe	Maintain existing underpass	Kikuyu Escarpment	0	0	0	0	0	0	0	0
2	25+325	Underpass	1 x 5.00 x 3.50	Kijabe	Demolition & reconstruction	Kijabe FR	0	0	0	0	0	0	0	0
3	53+375	Underpass	2 x 7.00 x 3.50	Naivasha East	New multipurpose underpass for KWSTI	Naivasha Sanctuary	0	0	0	0	0	0.89	0	0.89
4	69+235	Underpass	1 x 5.00 x 3.50	Marula	Demolition and reconstruction underpass for wildlife and livestock	Marula Estate	0	1.87	0.2847	11.46	0.1003	19.33	0.385	32.66
5	70+220	Overpass	1 x 30.00	Marula	New overpass, 30 m width	Marula Estate	0	2.59	0.2847	10.98	0.1003	16.90	0.385	30.48
6	71+340	Underpass	1 x 5.00 x 3.50	Marula	New underpass	Marula Estate	0	3.02	0.2847	11.40	0.1003	17.52	0.385	31.94
7	73+705	Underpass	3 x 5.00 x 3.50	Kigio	Demolition & reconstruction underpass	Marula Estate	0	7.56	0.2766	11.31	0.1003	17.38	0.3769	36.25
8	76+640	Underpass	1 x 7.00 x 3.50	Gilgil River	New underpass	Marula Estate	0	18.48	0.2766	7.25	0	15.98	0.2766	41.71
9	81+620	Underpass	1 x 7.00 x 3.50	Marula- Near Gilgil Junction	New underpass	Marula Estate	0	54.01	0	26.48	0	19.00	0	99.49
10	92+040	Underpass	1 x 5.00 x 3.50	Elmenteita-Kariandusi	Maintain multi-use culvert for wildlife and livestock	N/A	0	22.92	0	9.67	0	3.42	0	36.01
11	99+380	Overpass	1 x 30.00	Soysambu	New overpass	N/A	0	0.64	0	3.41	0	0.41	0	4.46
12	103+285	Underpass	1 x 5.00 x 3.50	Maendeleo-Soysambu	Demolition & reconstruction of a new underpass	Soysambu Conservancy	0	0	0	0.16	0	0	0	0.16
13	104+665	Underpass	1 x 5.00 x 3.50	Soysambu	Demolition and reconstruction of a new underpass	Soysambu Conservancy	0	0	0	0.14	0	0	0	0.14
14	106+215	Underpass	1 x 5.00 x 3.50	Mbaruk - Soysambu	Maintain existing underpass	Soysambu Conservancy	0	0	0	0.34	0	0	0	0.34
15	164+370	Underpass	1 x 7.00 x 4.50	Koibatek Forest - Near Itare Dam	New underpass for wildlife and livestock	Mount Londiani FR	0	0	0	0	0	0	0	0

Table 13: Favourable movement scenario wildlife crossing contribution to connectivity. A zero indicates that a particular wildlife crossing does not support connectivity. Values from green to red indicate important versus less important wildlife crossings according to the modelling.

							Buffalo		Giraffe		Zebra		All 3 species	
ID	**Chainage**	**Construction**	**Size**	**Location**	**Description**	**Conservation management**	**dIIC**	**Movement probability index**	**dIIC**	**Movement probability index**	**dIIC**	**Movement probability index**	**Sum of dIIC**	**Sum movement probability index**
1	22+825	Underpass	1 x 5.00 x 3.50	Kijabe	Maintain existing underpass	Kikuyu Escarpment	0.000071	11.35	0.000023	10.91	0	1.05	0.000094	23.30
2	25+325	Underpass	1 x 5.00 x 3.50	Kijabe	Demolition & reconstruction	Kijabe FR	0.000056	10.01	0.000023	10.93	0	0.69	0.000079	21.63
3	53+375	Underpass	2 x 7.00 x 3.50	Naivasha East	New multipurpose underpass for KWSTI	Naivasha Sanctuary	0	0.23	0.0004333	10.64	0	1.25	0.0004333	12.13
4	69+235	Underpass	1 x 5.00 x 3.50	Marula	Demolition and reconstruction underpass for wildlife and livestock	Marula Estate	0.008502	13.97	0.01234	12.23	0.09715	11.96	0.1180	38.15
5	70+220	Overpass	1 x 30.00	Marula	New overpass, 30 m width	Marula Estate	0.008502	12.52	0.01234	11.72	0.09715	10.45	0.1180	34.69
6	71+340	Underpass	1 x 5.00 x 3.50	Marula	New underpass	Marula Estate	0.01371	9.65	0.01234	12.16	0.09715	10.84	0.1232	32.65
7	73+705	Underpass	3 x 5.00 x 3.50	Kigio	Demolition & reconstruction underpass	Marula Estate	0.01371	12.71	0.01271	12.06	0.09715	10.75	0.1236	35.53
8	76+640	Underpass	1 x 7.00 x 3.50	Gilgil River	New underpass	Marula Estate	0.01371	17.44	0.01271	6.39	0	9.88	0.02642	33.72
9	81+620	Underpass	1 x 7.00 x 3.50	Marula-Near Gilgil Junction	New underpass	Marula Estate	0	21.07	0	21.68	0	11.78	0	54.53
10	92+040	Underpass	1 x 5.00 x 3.50	Elmenteita - Kariandusi	Maintain multi-use culvert for wildlife and livestock	N/A	0	10.67	0	10.80	0	2.28	0	23.75
11	99+380	Overpass	1 x 30.00	Soysambu	New overpass	N/A	0.01991	6.69	0.002238	20.52	0	27.36	0.02215	54.57
12	103+285	Underpass	1 x 5.00 x 3.50	Maendeleo-Soysambu	Demolition & reconstruction of a new underpass	Soysambu Conservancy	0.01991	25.29	0.001070	55.67	0.005818	24.11	0.02680	105.07
13	104+665	Underpass	1 x 5.00 x 3.50	Soysambu	Demolition and reconstruction of a new underpass	Soysambu Conservancy	0.01991	23.55	0.001070	36.21	0.005818	22.44	0.02680	82.20
14	106+215	Underpass	1 x 5.00 x 3.50	Mbaruk - Soysambu	Maintain existing underpass	Soysambu Conservancy	0.01991	24.24	0.001070	20.72	0	0	0.02098	44.96
15	164+370	Underpass	1 x 7.00 x 4.50	Koibatek Forest - Near Itare Dam	New underpass for wildlife and livestock	Mount Londiani FR	0	0	0	0	0	0	0	0

6.0 Final Summary and limitations

6.1. Summary

The modelling of the three conservation targets' habitat, connectivity patterns and wildlife crossing locations characterised a complex range of ecological patterns which can be used as a guide for decision support. The habitat suitability mapping successfully produced robust outputs which also concurred with the expert feedback and other mapping products in the region. The CAA modelling suggests that the RAA is isolated ecologically from the surrounding region. The habitat suitability modelling for the RAA identified two large connected agglomerations of protected areas and habitat linked from north to south to the west of the highway. The agglomeration in the north includes Lake Nakuru National Park, Soysambu Wildlife Conservancy and Lake Elementaita, and the agglomeration in the south include Marula Estate and Naivasha wildlife conservancies and formal protected areas such as Hell's Gate and Mount Longonot National Parks. The habitat suitability modelling consistently identified distance to protected areas as the most or second most important explanatory variable. Habitat, least-cost paths and movement probability were more commonly found to the west of the highway. The greatest area of habitat intersected by the road was in the southern agglomeration around Marula Estate. According to our results, these wildlife crossings are likely to provide the greatest benefit to ecological connectivity and persistence for these species and support the movement between core habitat i.e. large areas of highly suitable habitat. It is important to note that it is highly likely that species with different requirements to the three target species (e.g. elephant, small mammals, amphibians and reptiles) may require additional crossings to those identified assessed in this analysis.

The favourable movement scenario suggests that there is the potential for the two agglomerations which hold the majority of the suitable habitat in the RAA to be connected to other locations east of the highway including protected areas in north (Menengai) and southeast (Kikuyu Escarpment and Aberdare National Park). Feedback from a local-expert suggest that these connections and habitats do indeed exist and need to be considered from the conservation perspective.

The wildlife crossing assessments tend to identify wildlife crossing points around Marula as most important for movement (IDs 4,5,6 and 9). ID 9 had the highest sum movement probability index value for the default scenario and ID 12 had the highest sum movement probability index value for the favourable movement scenario.

The choice of wildlife crossing can be informed by the analysis, however, it is critical that these decisions are supported by other forms of data, such as field data and expert opinion. Potential wildlife crossing locations not addressed by our modelling such as for Mai-Mahiu (the lower road) may need to be addressed using other data sources.

6.2. Other considerations

The application of connectivity modelling approaches to the Nairobi-Nakuru-Mau Summit highway development provides a transparent and quantitative approach to assessing impacts and evaluating the effectiveness of wildlife crossing. However, it is important to recognise that spatial data accuracy, connectivity model type, target species and community and ecological parameterisation will all potentially affect the outcome of the modelling (Beier et al., 2009; Lechner et al., 2012; Lechner and Rhodes, 2016). Furthermore, a lack of data on key environmental explanatory layers, in particular fence lines and the protected area spatial data is likely to affect our modelling results. However, the impact of some of these drivers of uncertainty are likely to be made apparent by modelling multiple species with diverse characteristics and also through the default and favourable movement scenarios. Also, our modelling may not capture all the complexity of movement for such as Zebra migration movement patterns.

A key source of uncertainty for the analysis, which was addressed in part by the web-based expert survey, was finding adequate information to parameterise the model and occurrence data. The web-based survey was especially useful for overcoming difficulties in engaging key stakeholders and experts due to Covid restrictions, however, this approach doesn't provide for optimum levels of engagement in Kenya, in particularly with the government. While, the paramaterisation of the models was hampered by a lack of information from the academic literature, which is surprisingly sparse for such well known species. We did unsuccessfully, try to track down other sources of information from experts and the grey literature systematically through the web based survey and informally. While, the occurrence data available publicly through GBIF is missing known records, held in private databases such as by the Kenyan Wildlife Service (Appendix I) and uncertainty within the occurrence point database required us to model multiple Giraffe subspecies as one (Appendix J). However, what the model does provide is a characterisation of habitat and movement which is driven by data, and a repeatable and transparent process.

It is clear that the current understanding of the species ecology and publicly available data is limited meaning the result need to be considered as a baseline. This is especially the case for Kenya and other African countries more widely where so little quantitative data is available in the public domain to support our modelling. However, there are few examples such modelling being applied across African countries and Kenya is relatively advanced in terms of data knowledge and development; hence a great place to develop and apply such modelling. Given the expected increase in transport infrastructure across the region (Laurance et al., 2017), such approaches will be needed to support evidenced based decision making.

6.3. Final remarks

The modelling presented in this study represent a leading practice approach to undertaking an EIA with publicly available data, within the time-limitations and budget constraints of this project. The modelling shows that the Nairobi-Nakuru-Mau Summit highway represents a significant habitat for the conservation target species and movement in the region is ecologically important for connecting their habitat and likely to be impacted by the highway. The results provide a good baseline for analyses, but needs to be considered as just one input in the decision-making process along with other impacts unmeasured by the modelling when deciding on the final choice of wildlife crossing. It is recommended that ongoing monitoring and adaptive planning be undertaken as a precaution.

7.0 References

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8.0 Appendix

Appendix A: Workshop description and attendees

The survey was presented in an online workshop held on the 7th of April with 28 local experts and stakeholders which included wildlife experts and researchers, and members of environmental associations, NGOs, private land conservancy representatives. The list of attendees is available in the table below. The majority of the attendees have many years of experience in the local community and wildlife conservation, environmental, resource and land management as well as EIA. The experts were able to provide specific in-situ knowledge on the critical habitat or wildlife hotspot areas, wildlife behaviour and species occurrence in the study area. During the workshop discussion, the methods were critically examined and concerns such as additional data considerations and species suggestions were raised. The feedback received were taken into consideration to improve the methods and report.

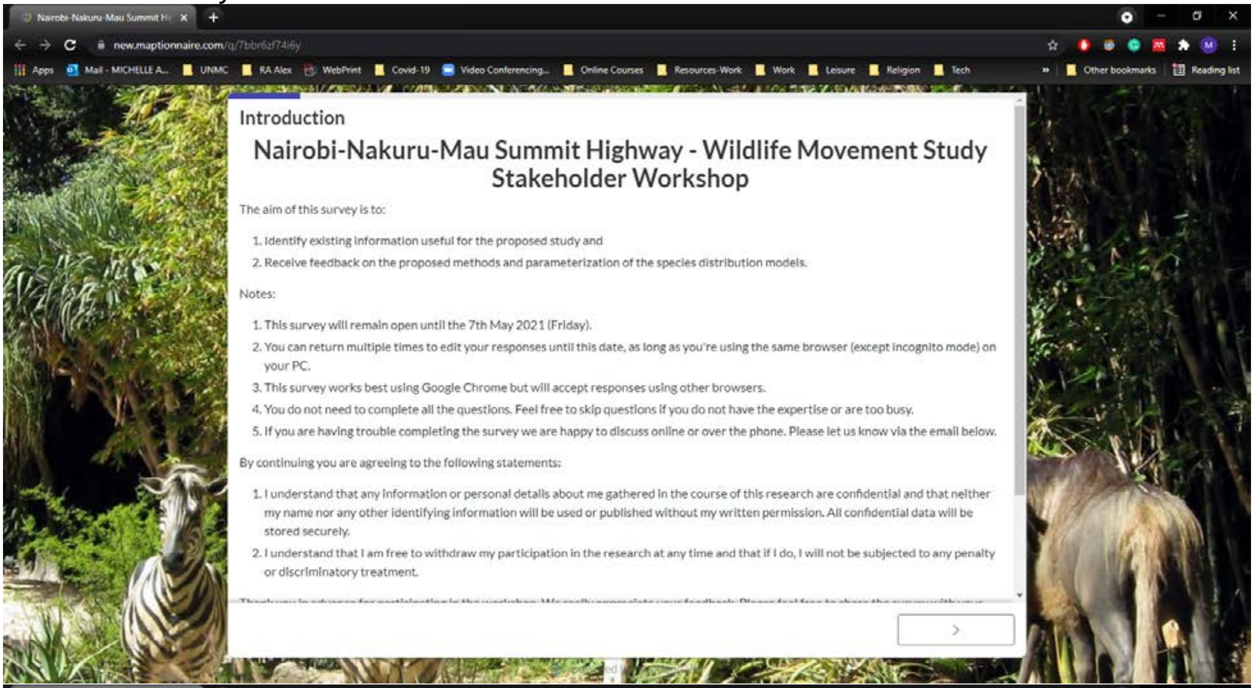
List of attendees of the Wildlife Movement Study Workshop and their expertise.

	Name	Corporation	Expertise identified based on web search
1	Waruingi, Lucy	African Conservation Centre (ACC)	Executive Director of ACC with 20 years of experience in conservation biology, natural resource management, community conservation and Geographic Information Systems (GIS)
2	Nyandire, Reinhard	African Sustainability Network (ASNET)	Executive Director of ASNET, MPhil. in Conservation Leadership Programme at University of Cambridge
3	Awori, Pat	Conservation Alliance of Kenya (CAK)	Board Member of CAK. Interests include East African history, wildlife conservation issues, and elephant behavior and conservation
4	Sang, Catherine	Development Corridors Partnership	Post-Doctoral Scientist with an experience of over 5 years in teaching, research and consultancy in water resources planning and management, hydrological modelling, applied GIS and Remote Sensing in Environmental Planning and Management, and Environmental Impact Assessment.
5	Collinson, Wendy	Endangered Wildlife Trust (EWT)	Field worker with the EWT's Wildlife and Transport Programme. MRes at Rhodes University, Grahamstown South Africa, examined the impacts of roads on South African wildlife.
6	Chiles, Sarah	Ewaso Lions & Grevy's Zebra Trust	Landscape Infrastructure Advisor at Ewaso Lions & Grevy's Zebra Trust
7	Fennessy, Julian	Giraffe Conservation Foundation (GCF)	Co-Director and Co-Founder of GCF with 20 years experience in species and habitat ecology, conservation and land management throughout the African continent and coordinates giraffe conservation efforts as the technical expert.
8	Muneza, Arthur	Giraffe Conservation Foundation (GCF)	GCF's East Africa Coordinator. PhD investigates a variety of factors affecting the survival and reproduction of giraffe populations across East Africa.
9	Ikime, Timothy	Kenya Wildlife Services (KWS)	Research Scientist at KWS
10	Mwangi, Peter	Kenya Wildlife Services (KWS)	Head-Environmental impact assessment programme at KWS
11	Dunn, Mairo	Lake Naivasha Riparian Association	No source available
12	Wanjala, Silas	Lake Naivasha Riparian Association	General Manager at Lake Naivasha Riparian Association
13	Lovatelli, Paolo	Marula Estates	Livestock and Wildlife Manager
14	Mwangi, Francis	Naivasha Municipal Board	Naivasha Municipal Board member

15	Weru, Sam	Naivasha Municipal Board	Naivasha Municipal Board Chairman
16	Juma, Absalom	Naivasha Professionals Association	Naivasha Professionals Association Board Member
17	Agwanda, Bernard	National Museums of Kenya	Research Scientist & Curator of Mammals at National Museums of Kenya
18	Kegora, Isaiah	Norken International	Head of Environment Department at Norken International
19	Mohamed, Bubicha	Norken International	Environmental Specialist undertaking Environmental Impact Assessment at Norken International
20	Sheppard, Donna	Rhino Ark	Community Conservation Specialist
21	Brandao, Cecile	Rift Valley Highway Limited (RVHL)	RVHL Chief Executive Officer and Board Director
22	Kamau, Kenneth	Rift Valley Highway Limited (RVHL)	No source available
23	Munyua, Allan	Rift Valley Highway Limited (RVHL)	RVHL Board Director
24	Boyd-Moss, Robin	Soysambu Conservancy	Soysambu Conservamcy CEO
25	Combes, Kathryn	Soysambu Conservancy	Fundraising Manager
26	Galgalo, Salad	Student University of Nairobi	BSc Environmental Conservation and Natural Resources Management
27	Kamau Wairimu, Stephen	The Forest	No source available
28	Muiru, Nelson	KENVO	Deputy Projects Coordinator

Appendix B: Maptionnaire survey content

Section 1: Survey Introduction and Consent.



Introduction

Nairobi-Nakuru-Mau Summit Highway - Wildlife Movement Study Stakeholder Workshop

The aim of this survey is to:

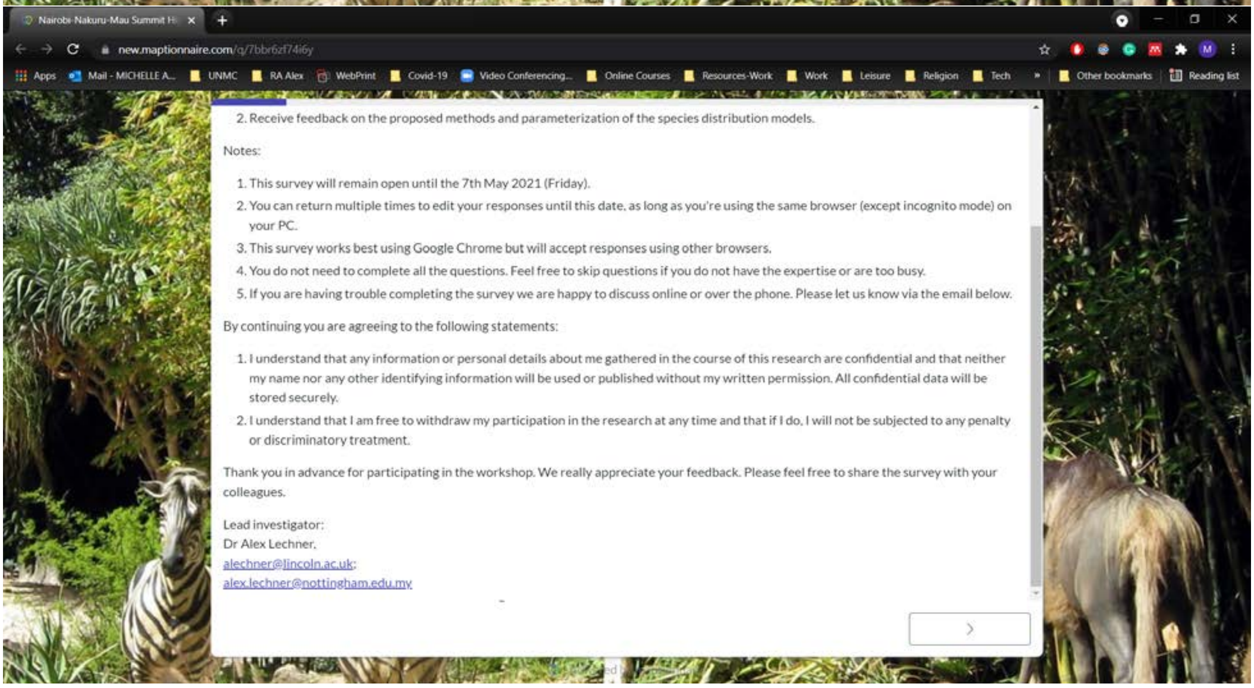
1. Identify existing information useful for the proposed study and
2. Receive feedback on the proposed methods and parameterization of the species distribution models.

Notes:

1. This survey will remain open until the 7th May 2021 (Friday).
2. You can return multiple times to edit your responses until this date, as long as you're using the same browser (except incognito mode) on your PC.
3. This survey works best using Google Chrome but will accept responses using other browsers.
4. You do not need to complete all the questions. Feel free to skip questions if you do not have the expertise or are too busy.
5. If you are having trouble completing the survey we are happy to discuss online or over the phone. Please let us know via the email below.

By continuing you are agreeing to the following statements:

1. I understand that any information or personal details about me gathered in the course of this research are confidential and that neither my name nor any other identifying information will be used or published without my written permission. All confidential data will be stored securely.
2. I understand that I am free to withdraw my participation in the research at any time and that if I do, I will not be subjected to any penalty or discriminatory treatment.



2. Receive feedback on the proposed methods and parameterization of the species distribution models.

Notes:

1. This survey will remain open until the 7th May 2021 (Friday).
2. You can return multiple times to edit your responses until this date, as long as you're using the same browser (except incognito mode) on your PC.
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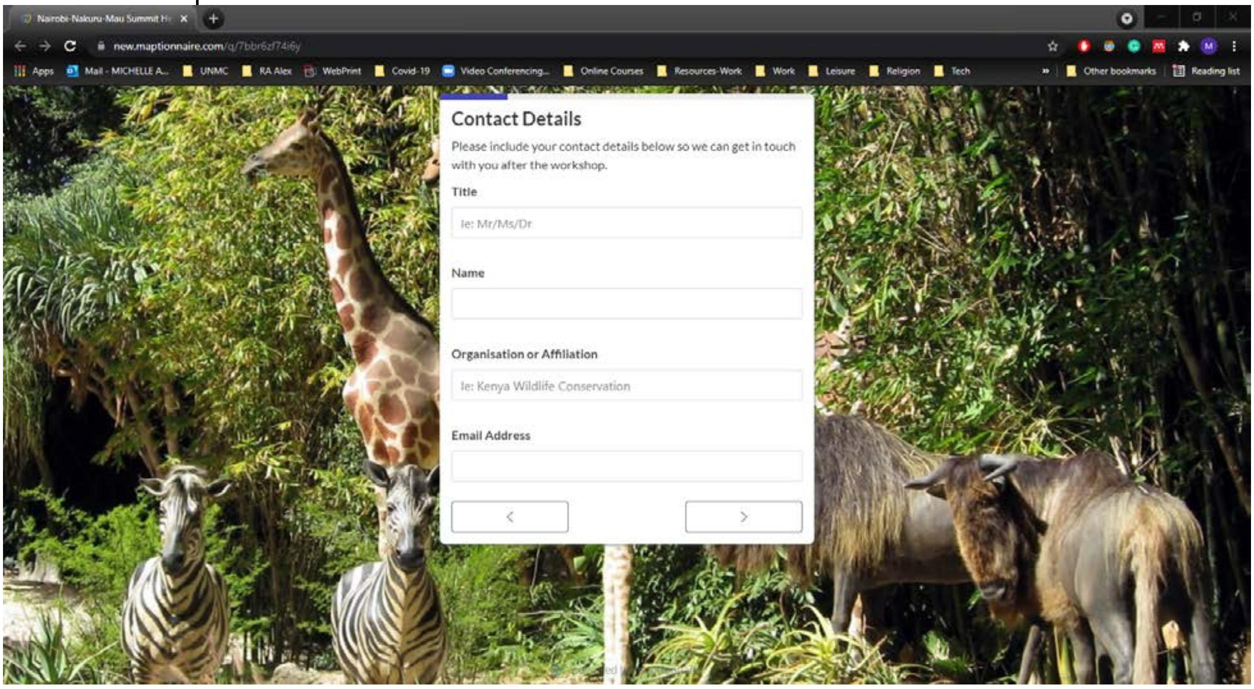
2. I understand that I am free to withdraw my participation in the research at any time and that if I do, I will not be subjected to any penalty or discriminatory treatment.

Thank you in advance for participating in the workshop. We really appreciate your feedback. Please feel free to share the survey with your colleagues.

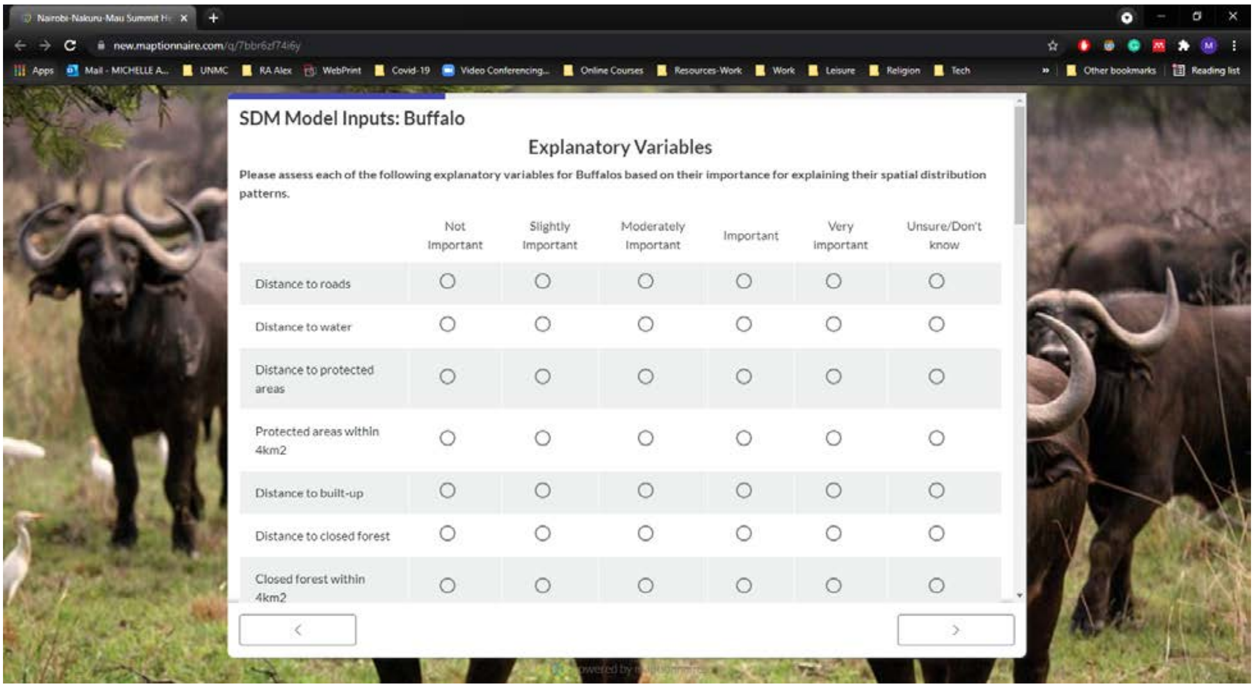
Lead investigator:
Dr Alex Lechner,
alechner@lincoln.ac.uk;
alex.lechner@nottingham.edu.my

Section 2: Respondent Contact Details.

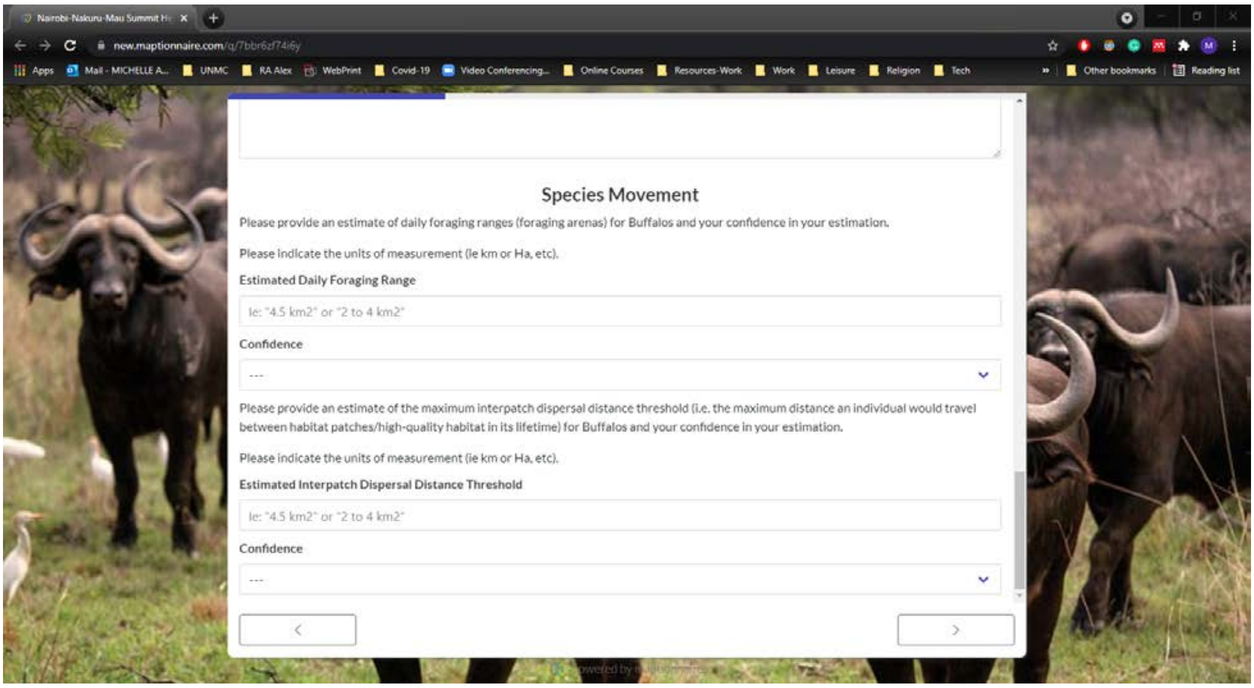


Section 3: Explanatory Variables and Movement Distances per Species.

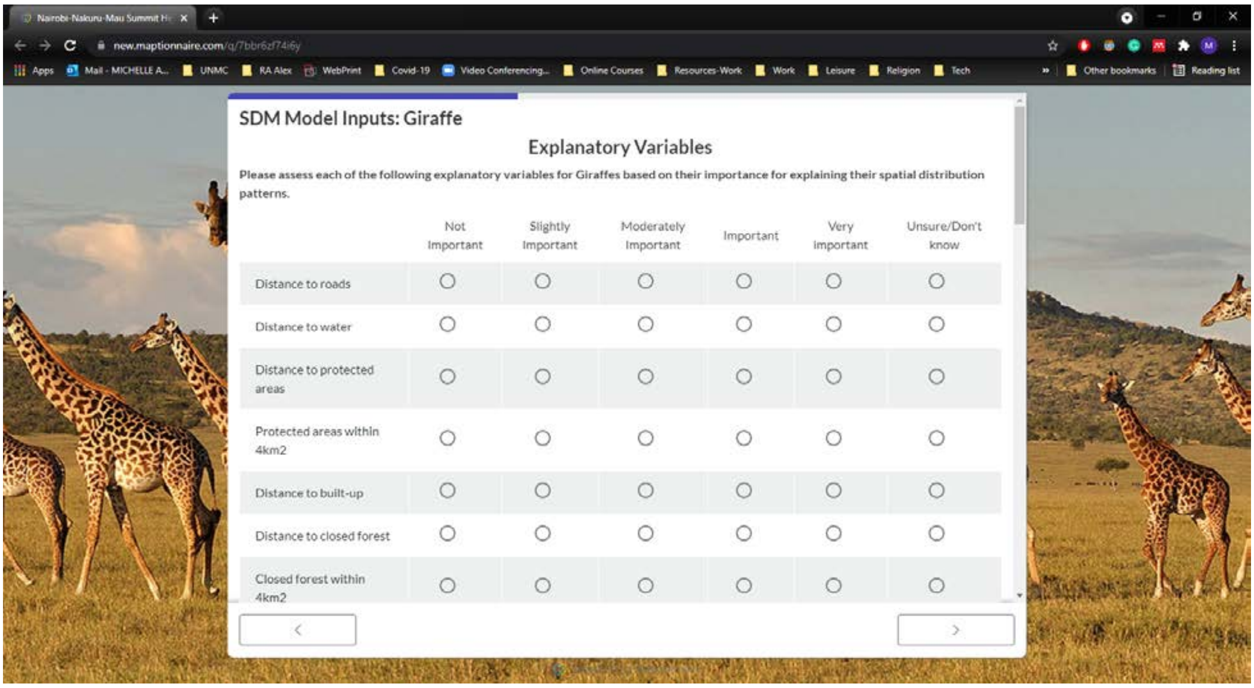
3.1. Buffalo



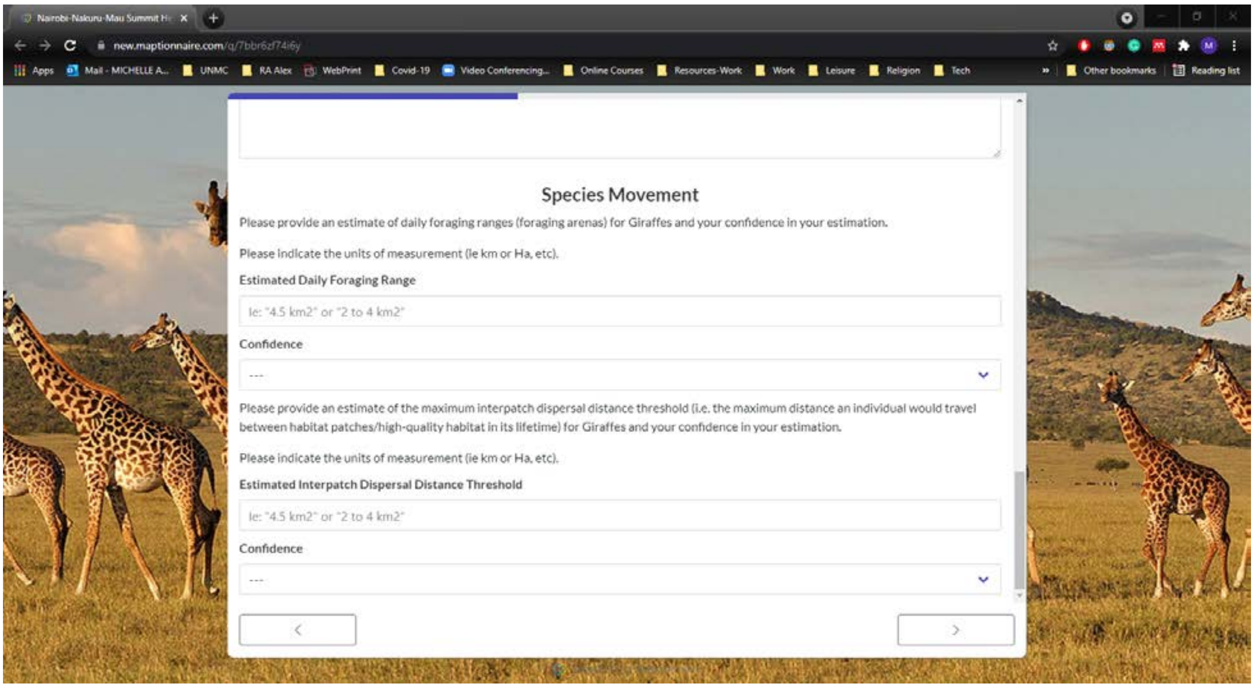
19 more variables when scrolled. For full list of explanatory variables, please refer to Table 6



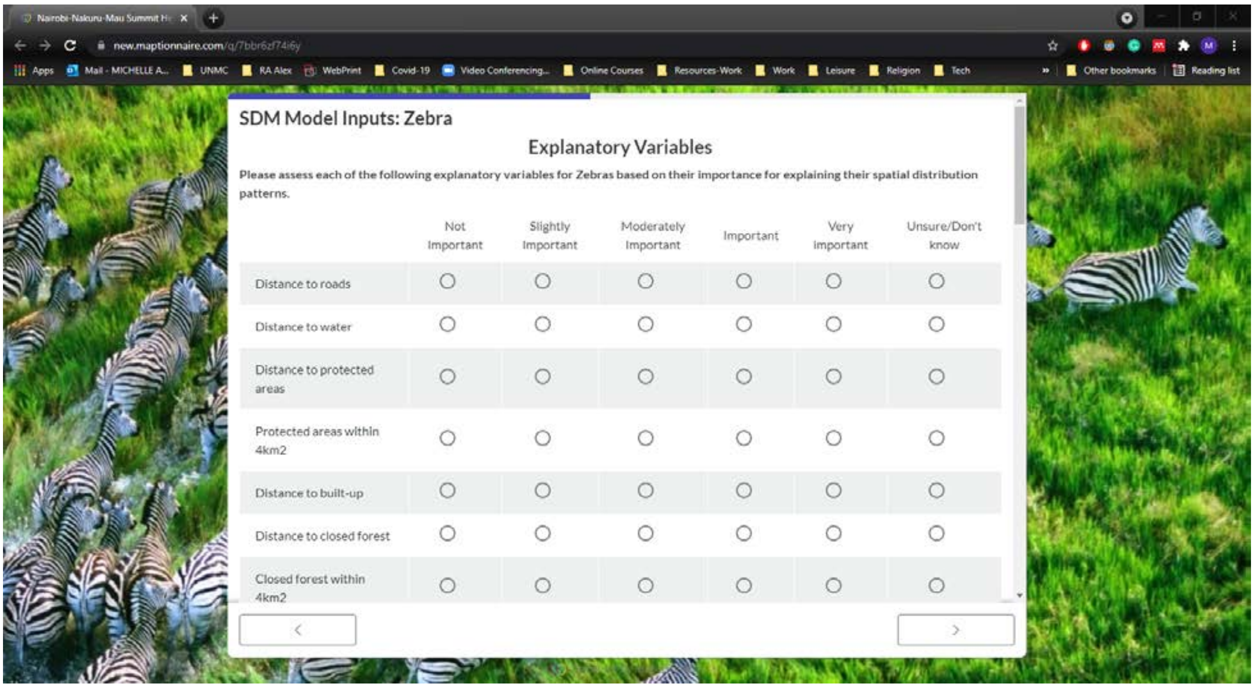
3.2. Giraffe



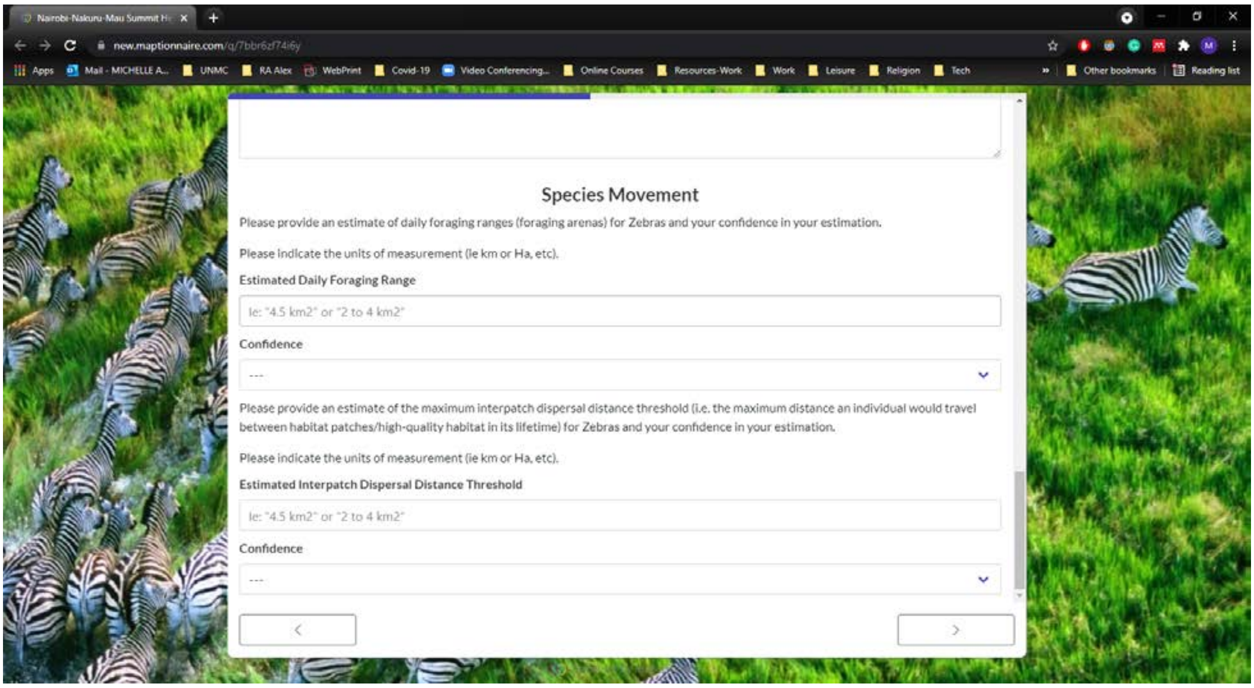
19 more variables when scrolled. For full list of explanatory variables, please refer to Table 6



3.3. Zebra

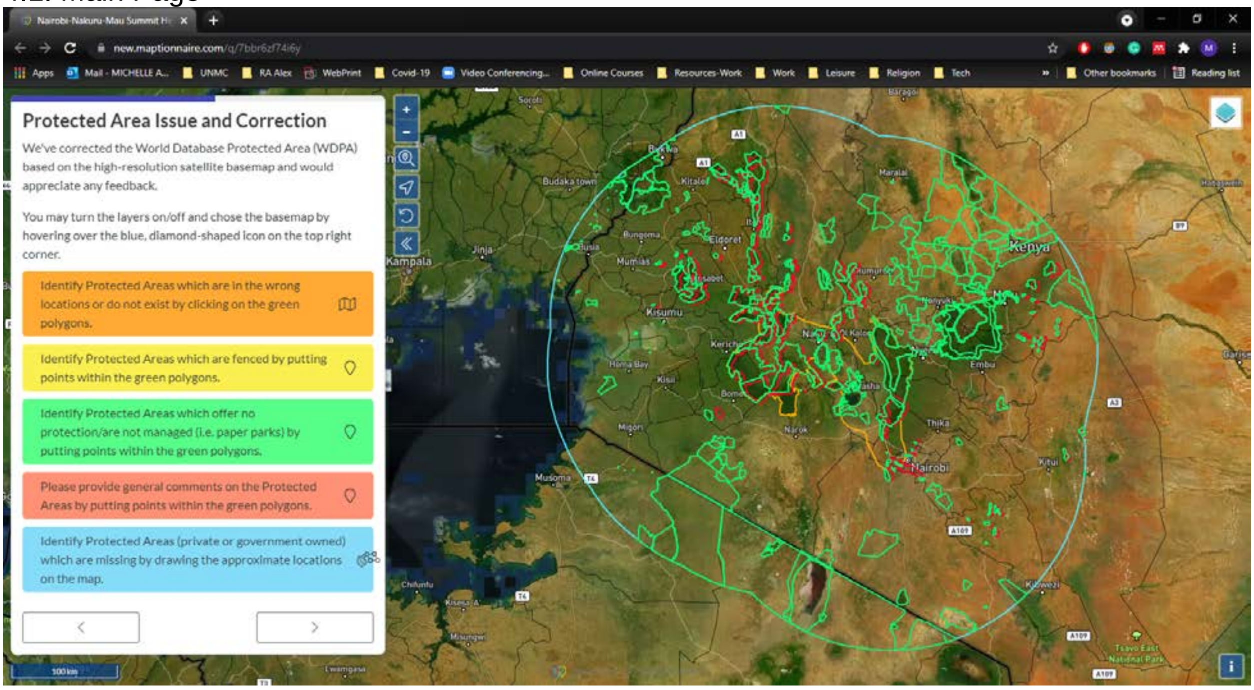


19 more variables when scrolled. For full list of explanatory variables, please refer to Table 6

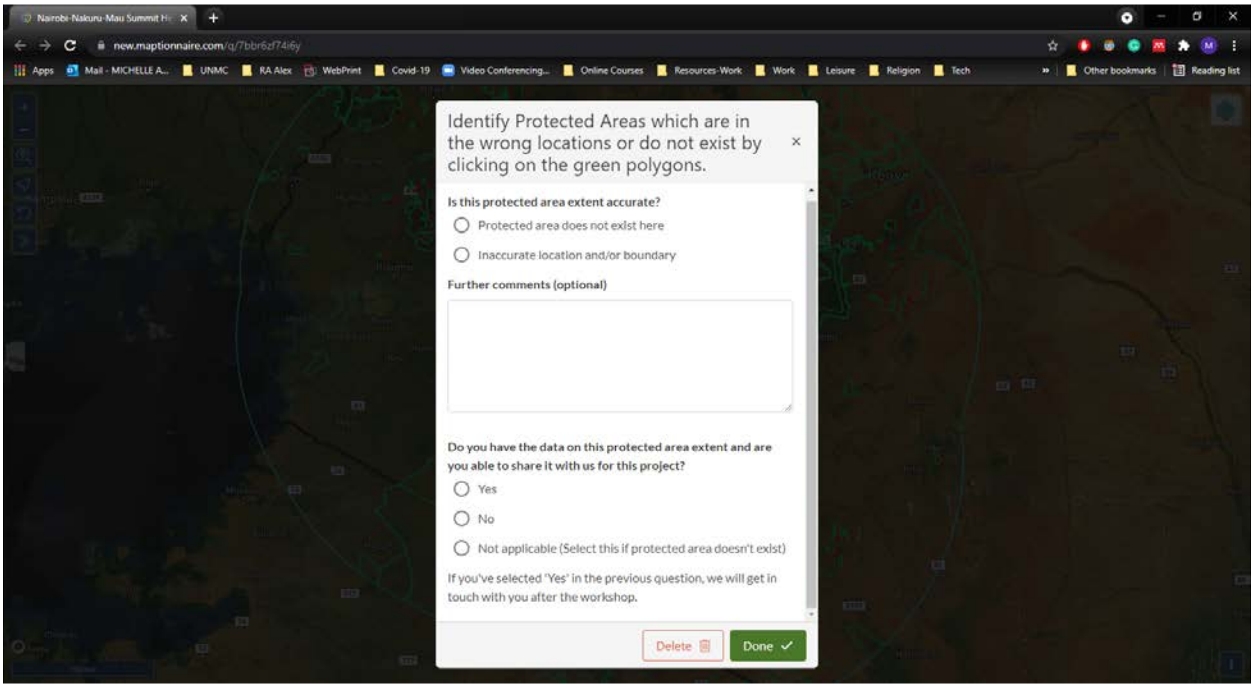


Section 4: Protected Area Dataset Correction.

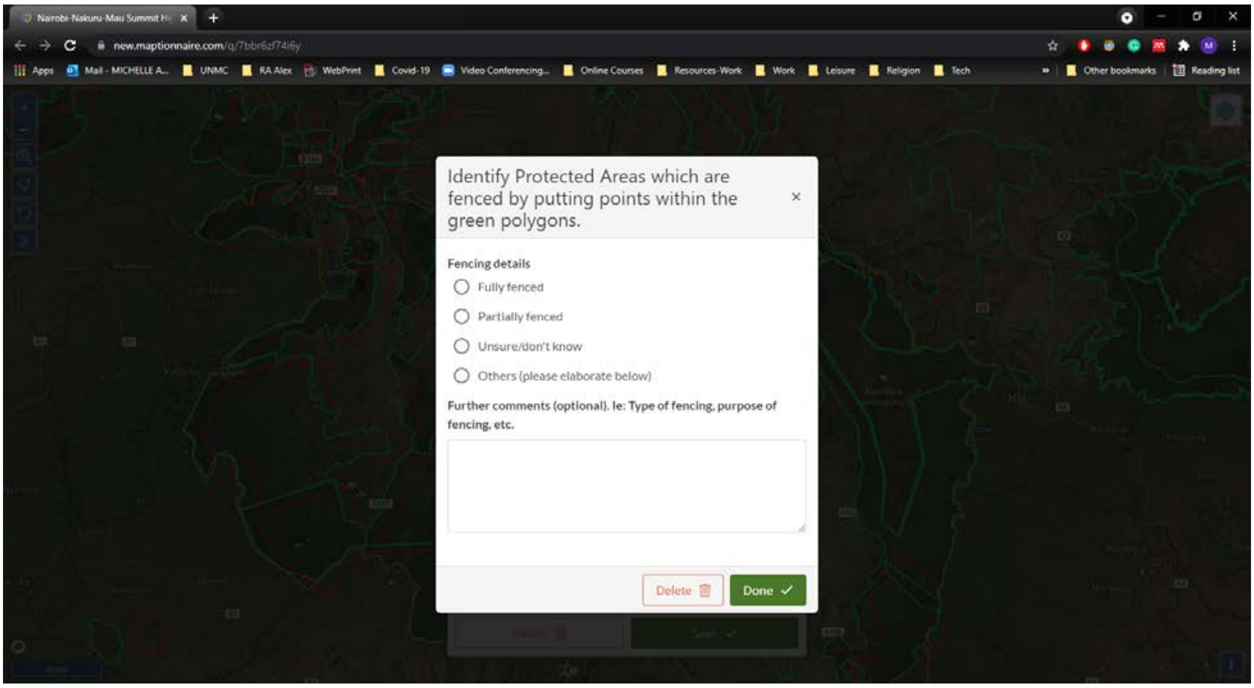
4.1. Main Page



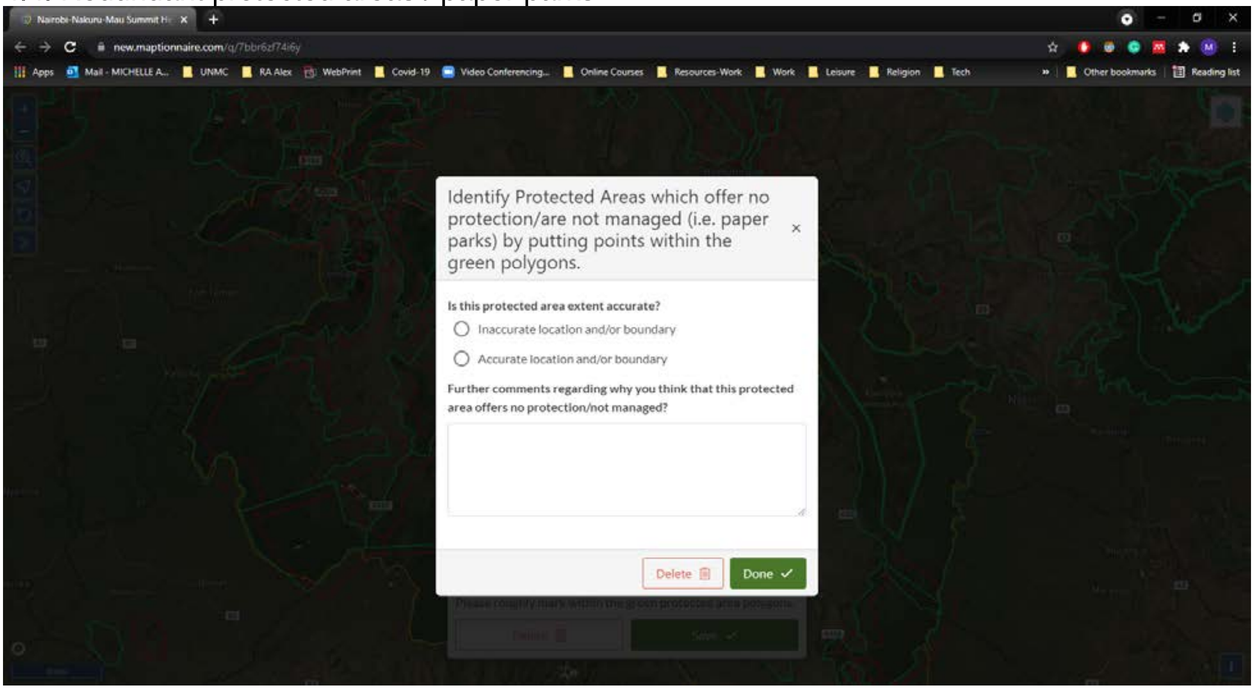
4.2. Protected area in incorrect locations or that do not exist



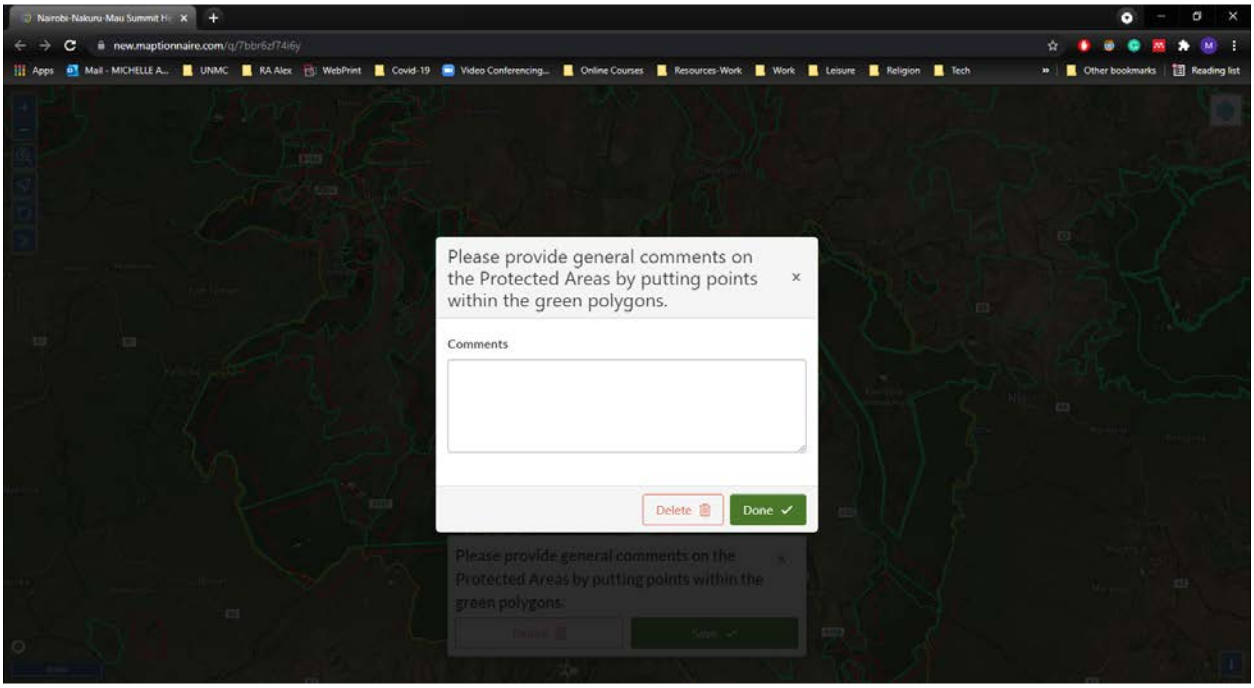
4.3. Protected area in incorrect locations or that do not exist



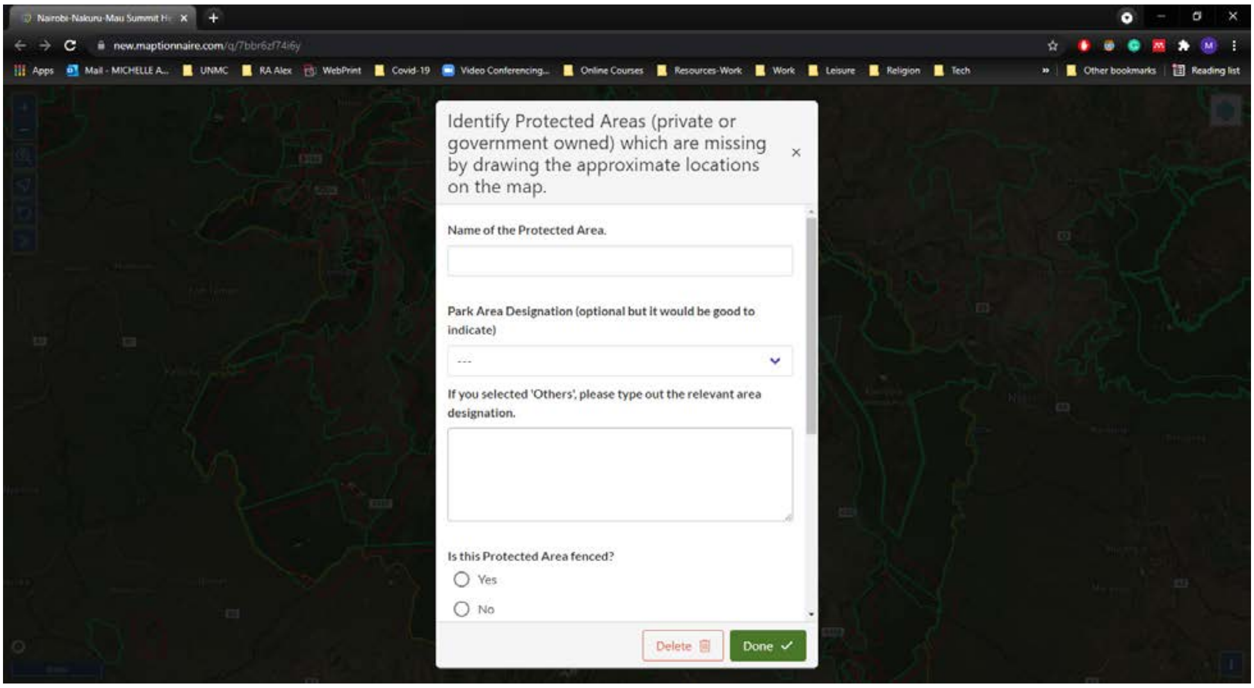
4.4. Redundant protected areas / paper parks



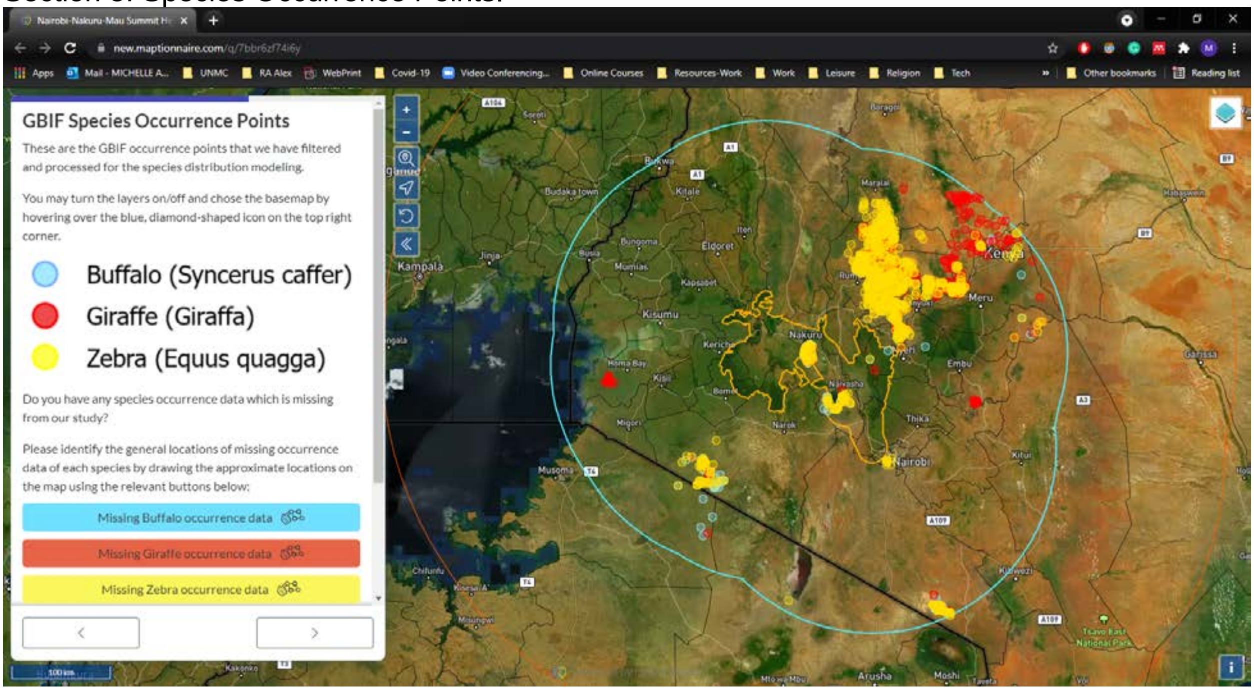
4.5. General Comments



4.6. Protected areas that are not in the dataset

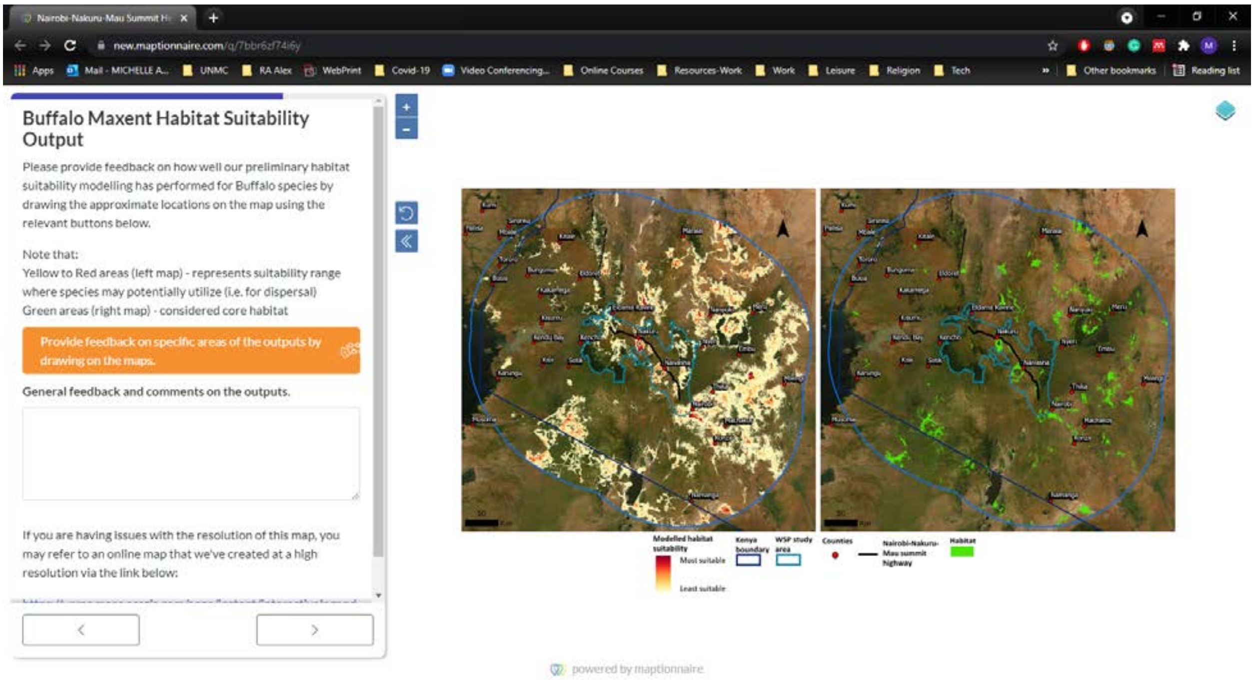


Section 5: Species Occurrence Points.



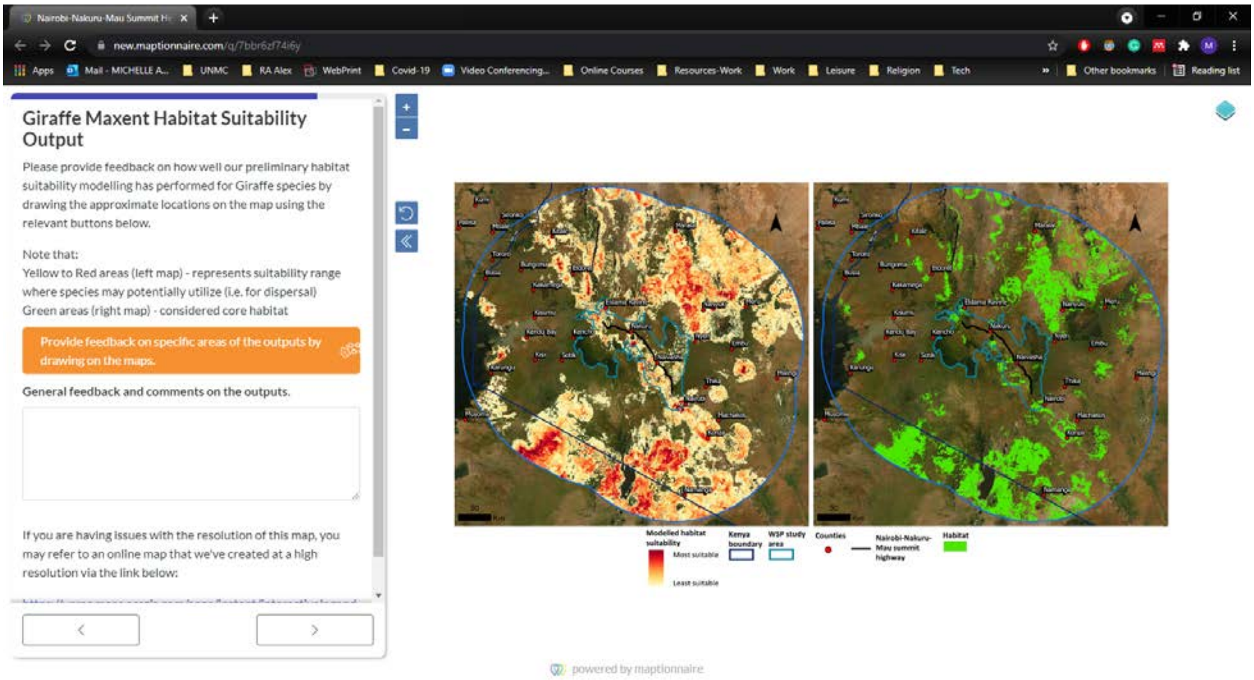
Section 6: Comments on preliminary habitat suitability outputs.

6.1. Buffalo



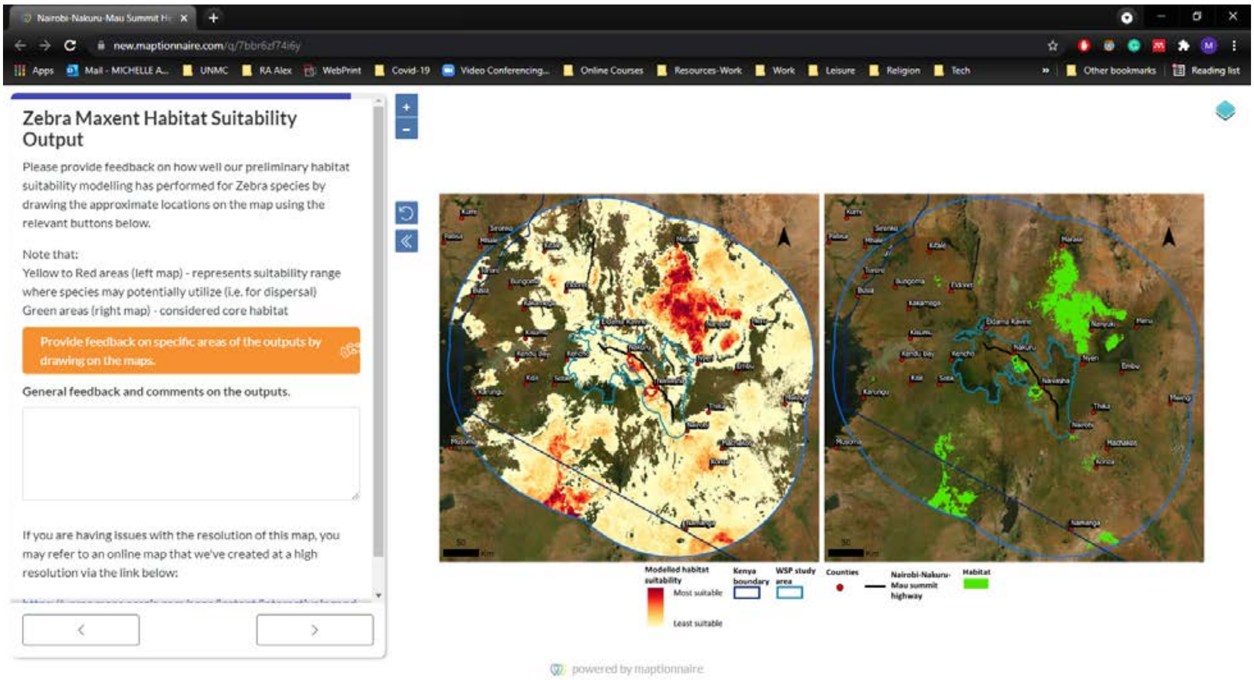
Link to the high resolution ArcGIS web map:
https://unmc.maps.arcgis.com/apps/instant/interactivelegend/index.html?appid=685cd0c0bbe14a2ca39849b1c7f31378

6.2. Giraffe



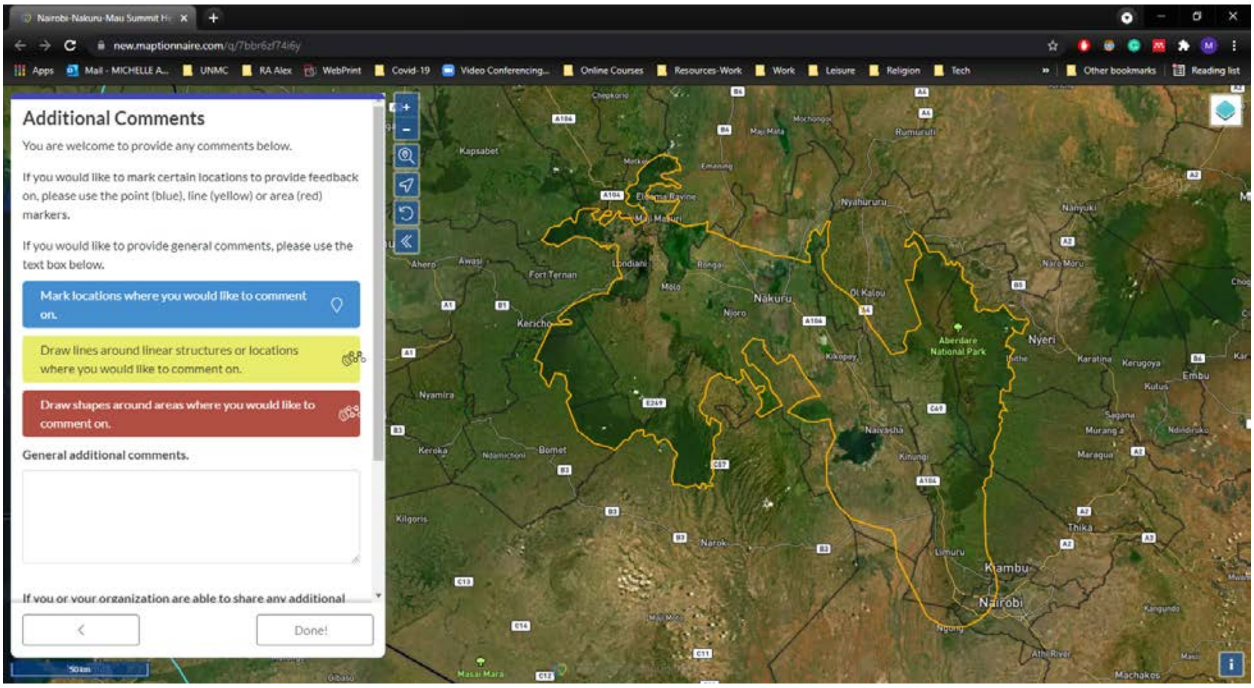
Link to the high resolution ArcGIS web map:
https://unmc.maps.arcgis.com/apps/instant/interactivelegend/index.html?appid=685cd0c0bbe14a2ca39849b1c7f31378

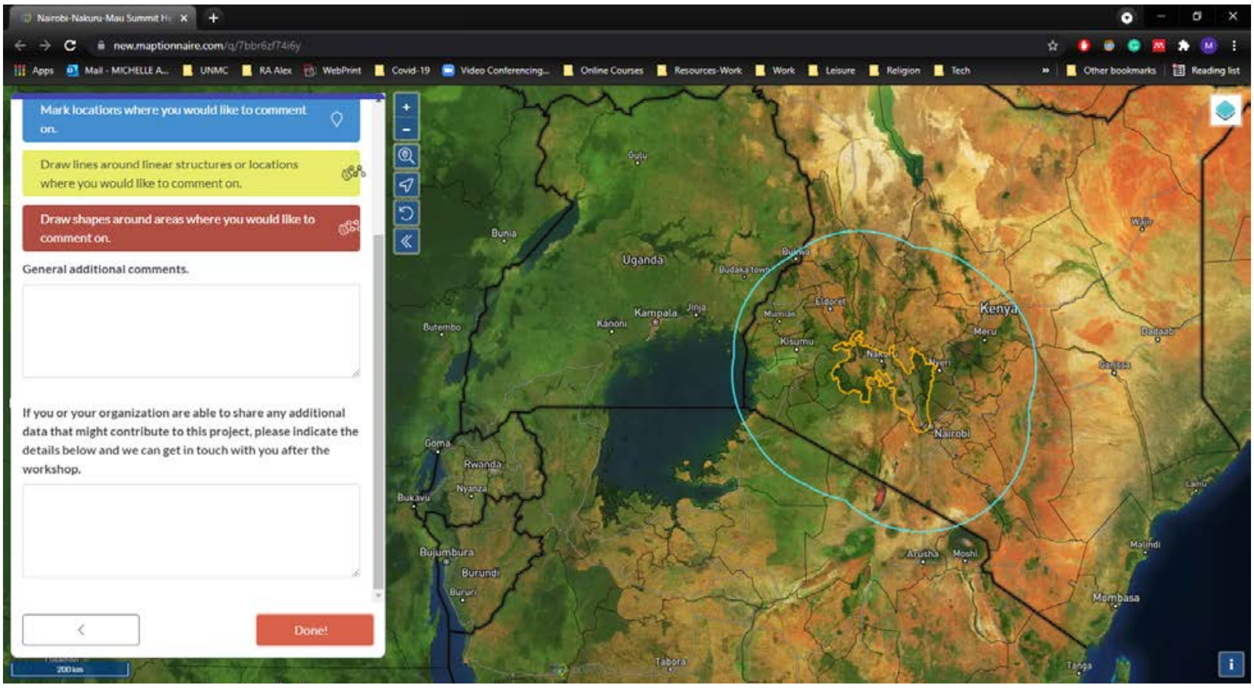
6.3. Zebra



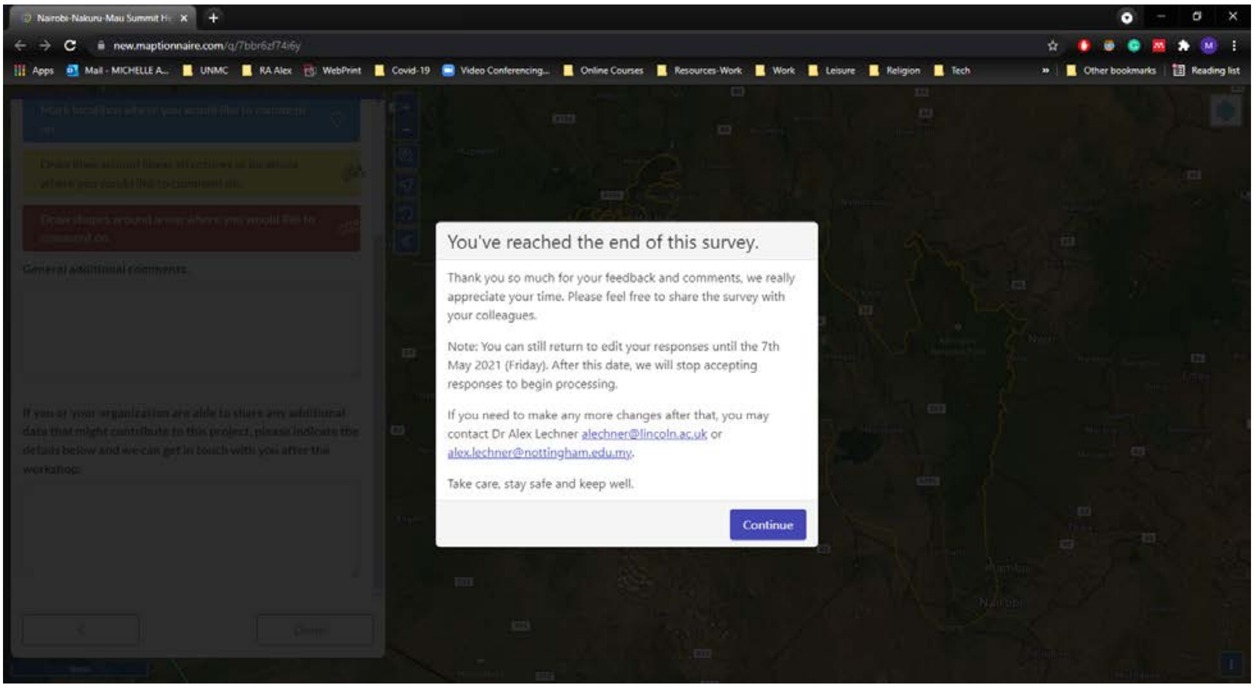
Link to the high resolution ArcGIS web map:
https://unmc.maps.arcgis.com/apps/instant/interactivelegend/index.html?appid=685cd0c0bbe14a2ca39849b1c7f31378

Section 7: Additional comments.





Section 8: End.



Appendix C: Giraffe occurrence points

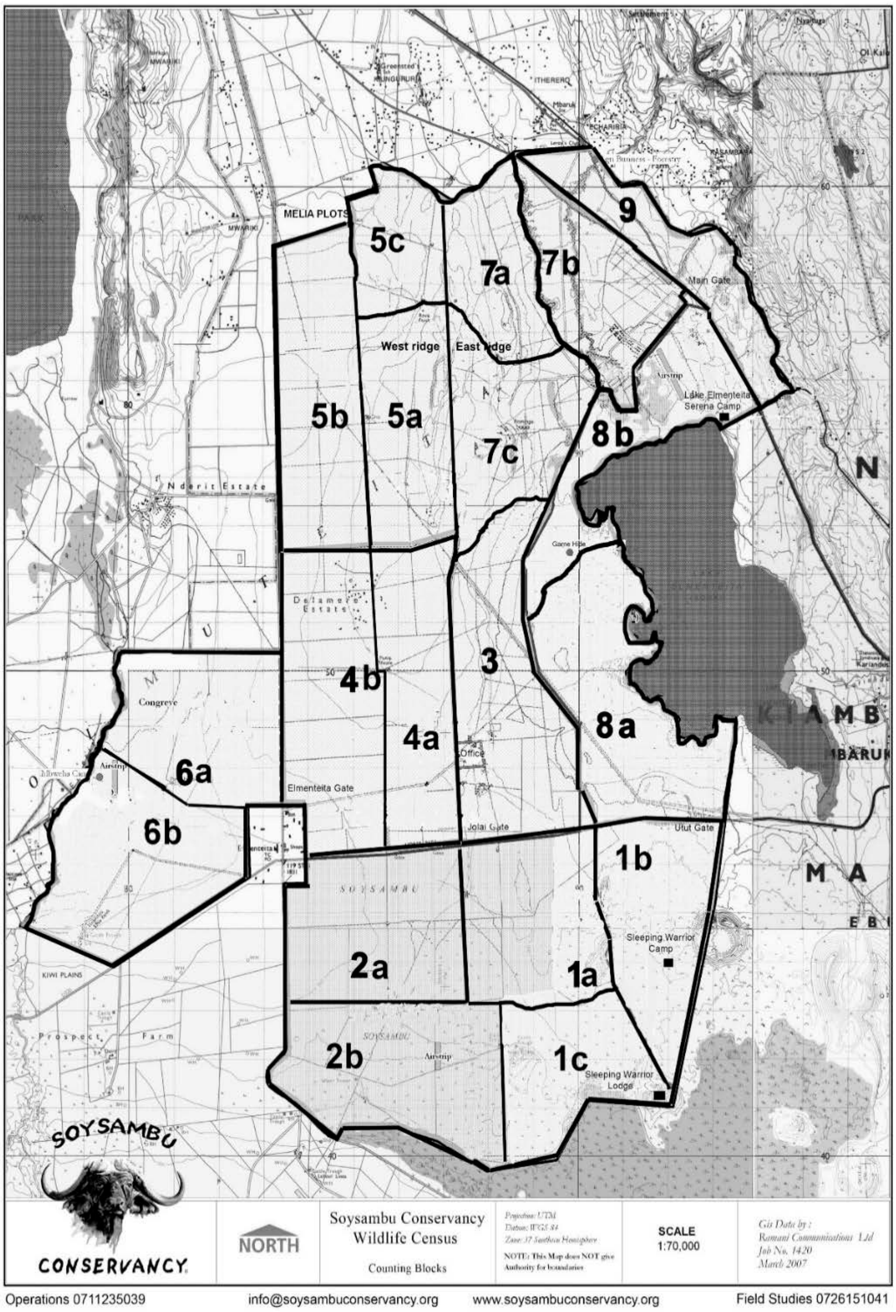
Below is a list of occurrence points from GBIF at various scales. These records have been cleaned as there were numerous issues with labelling. Furthermore, there were issues associated with a uncertainty in the records of the *G. camelopardalis rothschildi* (Rothschild's Giraffe) and *G. camelopardalis camelopardalis* (Nubian Giraffe) records. The final column describing spatially rarefied points represent points that are of sufficient quality for modelling.

Species	Extent	Unfiltered points	< 200 m coordinate uncertainty	Spatially rarefy by 200 m
G. camelopardalis (subspecies unspecified)	Kenya, Uganda and Tanzania	673	589	589
	Contextual Assessment Area	383	347	335
	Regional Assessment Area	4	0	0
G. tippelskirchi (Masai giraffe)	Kenya, and Tanzania	711	5	5
	Contextual Assessment Area	311	2	2
	Regional Assessment Area	50	1	1
G. reticulata (Reticulated giraffe)	Kenya	143	8	7
	Contextual Assessment Area	134	2	2
	Regional Assessment Area	3	1	1
G. camelopardalis rothschildi (Rothschild's Giraffe)	Kenya, and Uganda	858	679	78
	Contextual Assessment Area	755	662	61
	Regional Assessment Area	92	17	17

Appendix D: Soysambu Conservancy Wildlife presence only points

The Soysambu Conservancy is recognized as an important habitat for our conservation target species according to local experts, yet there are zero records available in GBIF. To address this error of omission, 20 points were manually added based on a wildlife census conducted in the park (Ramani Communications Ltd, 2007) using the following steps:

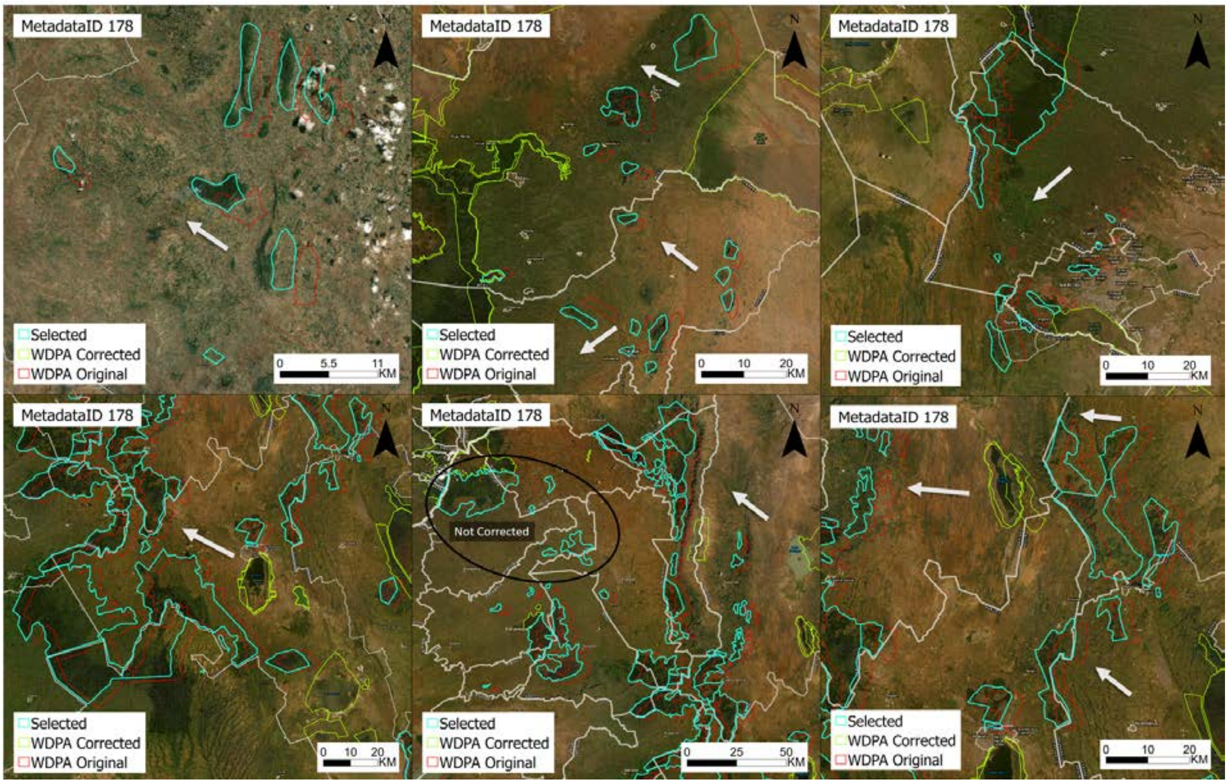
a) The points were added based on the number of aerial counts of each focal species for each of the 19 plots (see map of plots below).
b) For every plot that had a count higher than the average of all the 19 plots a single point was added to that plot near the center in an area that is visually suitable i.e. grassland based on the ArcGIS basemap (ESRI, 2021).



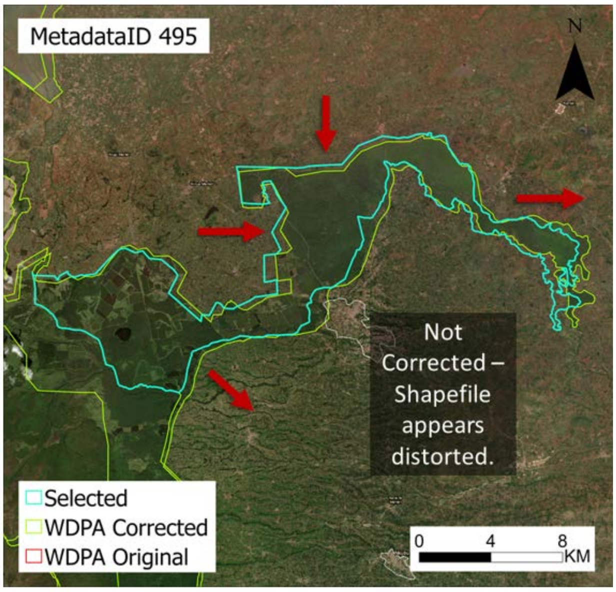
Map of the Soysambu Conservancy Wildlife Census (Ramani Communications Ltd, 2007)

Appendix E: World Database on Protected Area Mapping

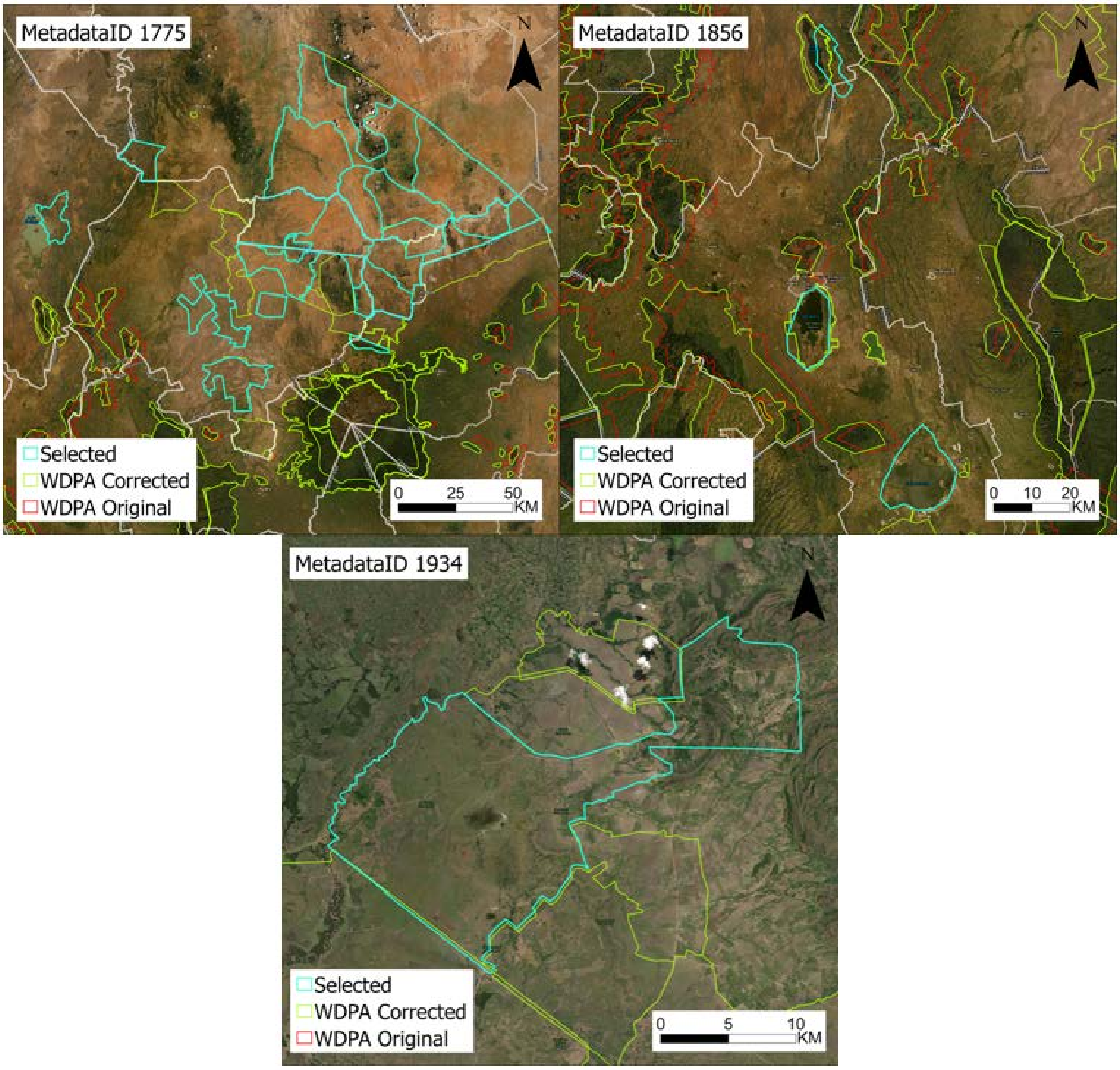
We noticed that certain protected areas in the World Database on Protected Area dataset did not align with the ArcGIS base map, sentinel true colour imagery and Copernicus land cover layers due to what appears to from data input, analysis or storage errors. In most cases the protected area boundaries just needed to be manually moved to ensure they lined up with existing land cover features. The following figures below give examples of some of the positional errors which were addressed.



Examples of protected area boundaries which were moved to line up with existing features on the ground.



For some protected areas their boundaries do not completely match features on the ground and were difficult to fix due to distortions in the boundaries.



In some locations there were no land cover features which corresponded with the protected area boundaries. For example, protected grasslands/plains may not look very different to the surrounded unprotected areas. There were some concerns these may be "paper parks".

To make the corrections the protected areas polygons were grouped based on their MetadataID field. Most of MetadataID groups had similar offset issues so could be fixed in one go, except for: 1) MetadataID 178 - 106 polygons and MetadataID 495 - 2 polygons.

This table summarises our qualitative assessment of the accuracy and the correction method used.

Accuracy	Total Polygons = 311	metadataid	data_title	resp_party	Correction method
Highly Inaccurate	106	**178**	Forest Administrative Boundaries and Stations, Kenya	Survey Branch of the Kenya Forest Department	Corrected at different angles
Inaccurate and slightly distorted	2	**495**	Protected areas of Kenya	UNEP, Nairobi, Kenya	No correction - Can't be fixed by moving
Relatively accurate but for some accuracy can't be deduced	48	**933**	Protected areas of Kenya	Kenya Wildlife Service (KWS)	No correction
Relatively accurate	5	**946**	UNESCO World Heritage Sites	IUCN World Heritage Programme	No correction
Relatively accurate	1	**988**	UNESCO-MAB Biosphere Reserve	UNESCO-MAB	No correction
Relatively accurate	3	**1442**	Uganda Wildlife Authority's protected areas	Uganda Wildlife Authority	No correction
Relatively accurate	52	**1708**	Forest Reserves of Uganda	National Forestry Authority, Plot 10/20, Spring Road, P.O. Box 70863, Kampala, Uganda	Some minor correction
Relatively accurate but for some accuracy can't be deduced	29	**1714**	Protected areas and community conservation areas in Kenya	African Wildlife Foundation (AWF)	No correction
Relatively accurate but for some accuracy can't be deduced	13	**1744**	National Parks of Tanzania	Tanzania National Parks (TANAPA)	No correction
Relatively accurate but for some accuracy can't be deduced	23	**1747**	Forest Reserves of Tanzania	Tanzania Forest Services (TFS) Agency	No correction
Relatively accurate but for majority accuracy can't be deduced	22	**1775**	Privately protected areas of Kenya	Zeitz Foundation, Kenya	No correction
Accuracy can't be deduced	5	**1856**	Ramsar Wetlands of International Importance	Ramsar Secretariat, on behalf of Ramsar Contracting Parties	No correction

Appendix F: Multicollinearity Test of Explanatory Environmental Variables

Multicollinearity test outputs for Buffalo and Giraffe. Highlighted values indicated the 3 levels of correlation index identified by literature: ≥ 0.8 (red), > 0.7 (orange) and > 0.5 (yellow).

	Layer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Distance to built-up	1.00	0.28	0.26	0.25	0.00	0.03	0.10	-0.06	0.13	-0.20	-0.22	-0.35	0.04	-0.10	0.11	-0.10	0.57	0.11	0.09	-0.13	0.09	0.10	0.13
2	Distance to closed forest	0.28	1.00	0.56	0.59	-0.36	0.09	0.14	-0.05	0.06	-0.43	-0.46	-0.40	0.26	0.12	-0.27	-0.35	0.34	0.32	0.35	-0.03	0.07	0.34	-0.30
3	Distance to open forests	0.26	0.56	1.00	0.98	-0.10	0.10	0.15	0.42	-0.10	-0.55	-0.59	-0.17	0.16	-0.19	-0.21	-0.27	0.43	0.26	0.26	-0.03	0.15	0.26	-0.24
4	Distance to closed+open forests	0.25	0.59	0.98	1.00	-0.15	0.11	0.17	0.38	-0.10	-0.58	-0.62	-0.21	0.16	-0.18	-0.24	-0.30	0.42	0.29	0.29	-0.03	0.17	0.30	-0.26
5	Landcover	0.00	-0.36	-0.10	-0.15	1.00	0.00	-0.05	0.24	-0.05	0.14	0.11	0.22	-0.20	-0.39	0.31	0.22	0.05	-0.19	-0.22	-0.01	-0.04	-0.21	0.30
6	Landform	0.03	0.09	0.10	0.11	0.00	1.00	0.44	0.02	-0.04	-0.16	-0.18	-0.08	0.01	-0.09	-0.20	-0.17	0.06	0.16	0.15	-0.01	0.03	0.15	-0.18
7	Landform_977	0.10	0.14	0.15	0.17	-0.05	0.44	1.00	-0.03	-0.04	-0.29	-0.31	-0.20	0.05	-0.10	-0.21	-0.28	0.12	0.30	0.28	-0.05	0.05	0.29	-0.17
8	Distance to ivestock	-0.06	-0.05	0.42	0.38	0.24	0.02	-0.03	1.00	-0.11	-0.14	-0.16	0.40	-0.11	-0.39	0.04	0.07	0.20	-0.04	-0.08	0.00	0.15	-0.06	-0.01
9	Distance to ater body	0.13	0.06	-0.10	-0.10	-0.05	-0.04	-0.04	-0.11	1.00	0.23	0.25	0.09	-0.07	0.18	0.08	0.14	-0.02	-0.13	-0.12	-0.09	-0.10	-0.12	0.09
10	NDVI	-0.20	-0.43	-0.55	-0.58	0.14	-0.16	-0.29	-0.14	0.23	1.00	0.93	0.32	-0.12	0.30	0.31	0.37	-0.37	-0.38	-0.37	-0.02	-0.19	-0.38	0.31
11	NDVI_977	-0.22	-0.46	-0.59	-0.62	0.11	-0.18	-0.31	-0.16	0.25	0.93	1.00	0.34	-0.13	0.36	0.31	0.40	-0.39	-0.41	-0.40	-0.02	-0.20	-0.40	0.32
12	Mean annual precipitation	-0.35	-0.40	-0.17	-0.21	0.22	-0.08	-0.20	0.40	0.09	0.32	0.34	1.00	-0.50	-0.16	0.15	0.45	-0.25	-0.33	-0.41	0.03	-0.09	-0.38	0.13
13	Seasonal precipitation	0.04	0.26	0.16	0.16	-0.20	0.01	0.05	-0.11	-0.07	-0.12	-0.13	-0.50	1.00	0.21	-0.07	-0.53	0.03	0.33	0.47	0.01	0.08	0.42	-0.09
14	Wetness	-0.10	0.12	-0.19	-0.18	-0.39	-0.09	-0.10	-0.39	0.18	0.30	0.36	-0.16	0.21	1.00	-0.10	-0.06	-0.31	0.00	0.03	0.02	-0.14	0.02	-0.08
15	Slope	0.11	-0.27	-0.21	-0.24	0.31	-0.20	-0.21	0.04	0.08	0.31	0.31	0.15	-0.07	-0.10	1.00	0.30	0.06	-0.29	-0.29	-0.04	-0.09	-0.29	0.77
16	Elevation	-0.10	-0.35	-0.27	-0.30	0.22	-0.17	-0.28	0.07	0.14	0.37	0.40	0.45	-0.53	-0.06	0.30	1.00	-0.14	-0.96	-0.98	0.03	-0.30	-0.98	0.31
17	Distance to roads	0.57	0.34	0.43	0.42	0.05	0.06	0.12	0.20	-0.02	-0.37	-0.39	-0.25	0.03	-0.31	0.06	-0.14	1.00	0.15	0.15	-0.08	0.14	0.15	0.08
18	Mean temperature of the coldest quarter	0.11	0.32	0.26	0.29	-0.19	0.16	0.30	-0.04	-0.13	-0.38	-0.41	-0.33	0.33	0.00	-0.29	-0.96	0.15	1.00	0.98	-0.04	0.29	0.99	-0.29
19	Mean temperature of the warmest quarter	0.09	0.35	0.26	0.29	-0.22	0.15	0.28	-0.08	-0.12	-0.37	-0.40	-0.41	0.47	0.03	-0.29	-0.98	0.15	0.98	1.00	-0.03	0.30	1.00	-0.30
20	Nightlights_mean_977	-0.13	-0.03	-0.03	-0.03	-0.01	-0.01	-0.05	0.00	-0.09	-0.02	-0.02	0.03	0.01	0.02	-0.04	0.03	-0.08	-0.04	-0.03	1.00	-0.03	-0.03	-0.06
21	Distance to protected areas	0.09	0.07	0.15	0.17	-0.04	0.03	0.05	0.15	-0.10	-0.19	-0.20	-0.09	0.08	-0.14	-0.09	-0.30	0.14	0.29	0.30	-0.03	1.00	0.30	-0.10
22	Mean annual temperature	0.10	0.34	0.26	0.30	-0.21	0.15	0.29	-0.06	-0.12	-0.38	-0.40	-0.38	0.42	0.02	-0.29	-0.98	0.15	0.99	1.00	-0.03	0.30	1.00	-0.30
23	Ruggedness_977	0.13	-0.30	-0.24	-0.26	0.30	-0.18	-0.17	-0.01	0.09	0.31	0.32	0.13	-0.09	-0.08	0.77	0.31	0.08	-0.29	-0.30	-0.06	-0.10	-0.30	1.00

Multicollinearity test outputs for Zebra. Highlighted values indicated the 3 levels of correlation index identified by literature: ≥ 0.8 (red), > 0.7 (orange) and > 0.5 (yellow).

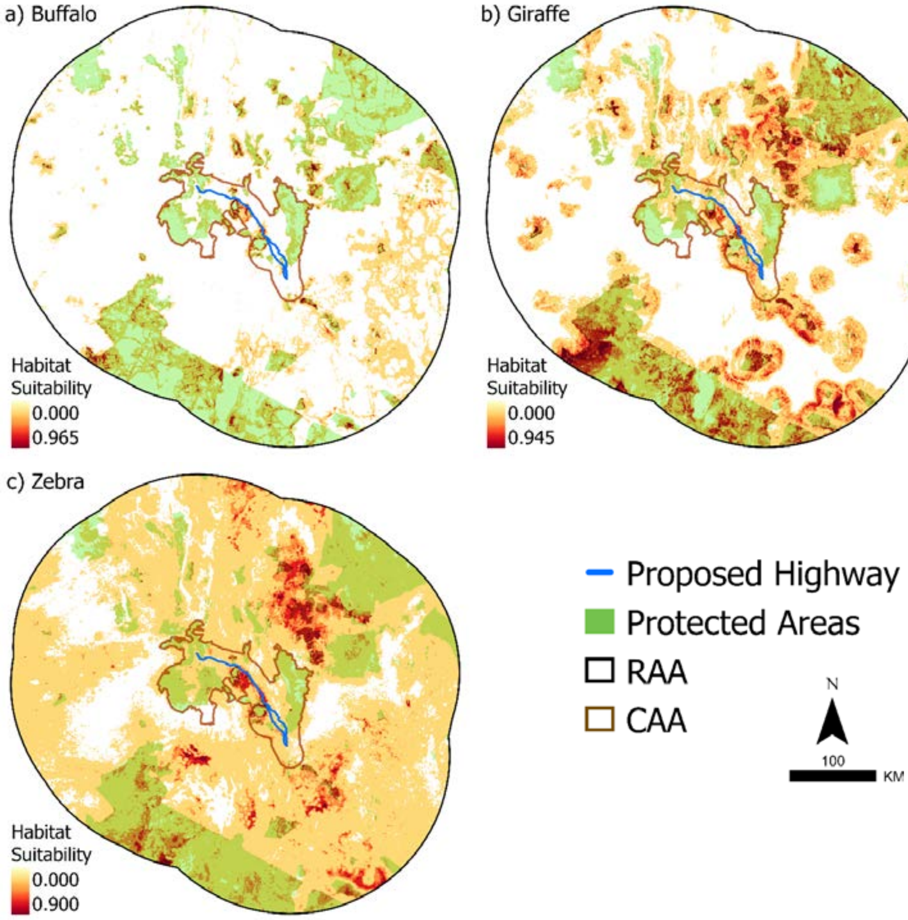
	Layer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Distance to built-up	1.00	0.28	0.06	0.25	0.00	0.03	0.10	-0.06	0.13	-0.20	-0.22	-0.35	0.04	-0.10	0.11	-0.10	0.57	0.11	0.09	-0.13	0.09	0.10	0.13
2	Distance to closed forest	0.28	1.00	-0.37	0.59	-0.36	0.09	0.15	-0.05	0.06	-0.43	-0.46	-0.40	0.26	0.12	-0.27	-0.35	0.34	0.32	0.35	-0.03	0.07	0.34	-0.30
3	Distance to open forests	0.06	-0.37	1.00	-0.31	0.50	-0.05	-0.01	-0.12	0.03	0.23	0.24	-0.02	-0.17	-0.11	0.29	0.11	0.00	-0.07	-0.09	-0.04	-0.02	-0.09	0.37
4	Distance to closed+open forests	0.25	0.59	-0.31	1.00	-0.15	0.11	0.17	0.38	-0.10	-0.58	-0.62	-0.21	0.16	-0.18	-0.24	-0.30	0.42	0.29	0.29	-0.03	0.17	0.30	-0.26
5	Landcover	0.00	-0.36	0.50	-0.15	1.00	0.00	-0.06	0.24	-0.05	0.14	0.11	0.22	-0.20	-0.39	0.31	0.22	0.05	-0.19	-0.22	-0.01	-0.04	-0.21	0.30
6	Landform	0.03	0.09	-0.05	0.11	0.00	1.00	0.40	0.02	-0.04	-0.16	-0.18	-0.08	0.01	-0.09	-0.20	-0.17	0.06	0.16	0.15	-0.01	0.03	0.15	-0.17
7	Landform_4000	0.10	0.15	-0.01	0.17	-0.06	0.40	1.00	-0.04	-0.04	-0.30	-0.32	-0.21	0.06	-0.10	-0.21	-0.29	0.13	0.31	0.29	-0.05	0.05	0.30	-0.15
8	Distance to ivestock	-0.06	-0.05	-0.12	0.38	0.24	0.02	-0.04	1.00	-0.11	-0.14	-0.16	0.40	-0.11	-0.39	0.04	0.07	0.20	-0.04	-0.08	0.00	0.15	-0.06	-0.01
9	Distance to ater body	0.13	0.06	0.03	-0.10	-0.05	-0.04	-0.04	-0.11	1.00	0.23	0.25	0.09	-0.07	0.18	0.08	0.14	-0.02	-0.13	-0.12	-0.09	-0.10	-0.12	0.09
10	NDVI	-0.20	-0.43	0.23	-0.58	0.14	-0.16	-0.30	-0.14	0.23	1.00	0.93	0.32	-0.12	0.30	0.31	0.37	-0.37	-0.38	-0.37	-0.02	-0.19	-0.38	0.30
11	NDVI_4000	-0.22	-0.46	0.24	-0.62	0.11	-0.18	-0.32	-0.16	0.25	0.93	1.00	0.34	-0.13	0.36	0.30	0.40	-0.40	-0.41	-0.40	-0.02	-0.20	-0.41	0.32
12	Mean annual precipitation	-0.35	-0.40	-0.02	-0.21	0.22	-0.08	-0.21	0.40	0.09	0.32	0.34	1.00	-0.50	-0.16	0.15	0.45	-0.25	-0.33	-0.41	0.03	-0.09	-0.38	0.13
13	Seasonal precipitation	0.04	0.26	-0.17	0.16	-0.20	0.01	0.06	-0.11	-0.07	-0.12	-0.13	-0.50	1.00	0.21	-0.07	-0.53	0.03	0.33	0.47	0.01	0.08	0.42	-0.08
14	Wetness	-0.10	0.12	-0.11	-0.18	-0.39	-0.09	-0.10	-0.39	0.18	0.30	0.36	-0.16	0.21	1.00	-0.10	-0.06	-0.31	0.00	0.03	0.02	-0.14	0.02	-0.07
15	Slope	0.11	-0.27	0.29	-0.24	0.31	-0.20	-0.21	0.04	0.08	0.31	0.30	0.15	-0.07	-0.10	1.00	0.30	0.06	-0.29	-0.29	-0.04	-0.09	-0.29	0.75
16	Elevation	-0.10	-0.35	0.11	-0.30	0.22	-0.17	-0.29	0.07	0.14	0.37	0.40	0.45	-0.53	-0.06	0.30	1.00	-0.14	-0.96	-0.98	0.03	-0.30	-0.98	0.31
17	Distance to roads	0.57	0.34	0.00	0.42	0.05	0.06	0.13	0.20	-0.02	-0.37	-0.40	-0.25	0.03	-0.31	0.06	-0.14	1.00	0.15	0.15	-0.08	0.14	0.15	0.08
18	Mean temperature of the coldest quarter	0.11	0.32	-0.07	0.29	-0.19	0.16	0.31	-0.04	-0.13	-0.38	-0.41	-0.33	0.33	0.00	-0.29	-0.96	0.15	1.00	0.98	-0.05	0.29	0.99	-0.29
19	Mean temperature of the warmest quarter	0.09	0.35	-0.09	0.29	-0.22	0.15	0.29	-0.08	-0.12	-0.37	-0.40	-0.41	0.47	0.03	-0.29	-0.98	0.15	0.98	1.00	-0.03	0.30	1.00	-0.30
20	Nightlights_mean_4000	-0.13	-0.03	-0.04	-0.03	-0.01	-0.01	-0.05	0.00	-0.09	-0.02	-0.02	0.03	0.01	0.02	-0.04	0.03	-0.08	-0.05	-0.03	1.00	-0.03	-0.03	-0.06
21	Distance to protected areas	0.09	0.07	-0.02	0.17	-0.04	0.03	0.05	0.15	-0.10	-0.19	-0.20	-0.09	0.08	-0.14	-0.09	-0.30	0.14	0.29	0.30	-0.03	1.00	0.30	-0.11
22	Mean annual temperature	0.10	0.34	-0.09	0.30	-0.21	0.15	0.30	-0.06	-0.12	-0.38	-0.41	-0.38	0.42	0.02	-0.29	-0.98	0.15	0.99	1.00	-0.03	0.30	1.00	-0.30
23	Ruggedness_4000	0.13	-0.30	0.37	-0.26	0.30	-0.17	-0.15	-0.01	0.09	0.30	0.32	0.13	-0.08	-0.07	0.75	0.31	0.08	-0.29	-0.30	-0.06	-0.11	-0.30	1.00

Literature on the correlation index threshold for multicollinearity tests.

Text directly from paper	High Correlation Value, r	Reference
To avoid including highly correlated environmental variables, we tested for multicollinearity. Since none of the variables were highly correlated (r ≥ 0.8, Behdarvand et al. 2014) all were included in the models	≥ 0.8	(Cerqueira et al., 2021)
We tested the covariates for multicollinearity using Pearson’s correlation matrix (STATS package, R 3.1.1). We did not include covariates in the same candidate model that were correlated at > 0.5.	> 0.5	(de la Torre et al., 2021, 2018)
Then, we evaluated multicollinearity between covariates by means of a Spearman rank correlation matrix. Closely correlated covariates (r>|0.8|) were targeted and one variable per pair of covariates was chosen by minimizing the Akaike Information Criterion (AIC) in a binary logistic regression (Burnham and Anderson 2002).	>|0.8|	(Girardet et al., 2015)
In order to remove any variables that were highly correlated before generating the models, we calculated a correlation matrix using Pearson’s technique and selected only the variables for which r < 0.70 (Booth et al, 1994)	> 0.7	(Kabir et al., 2017)
None of the included variables showed signs of multicollinearity or strong correlations, as determined from a variance inflation factor (VIF) analysis with a threshold of VIF > 10, and a Pearson's correlation test with a threshold of r > 0.7	> 0.7	(Rød-Eriksen et al., 2020)
Groups of intercorrelated variables (i.e. those whose correlation was expressed with a Pearson value|r| ≥ 0.5) were excluded from analysis. We adopted this particularly restrictive threshold (Booth et al. 1994; Dormann et al. 2013) because landscape metrics have been shown to be highly redundant and intercorrelated (Cushman et al. 2008).	≥ 0.5	(Ducci et al., 2015)

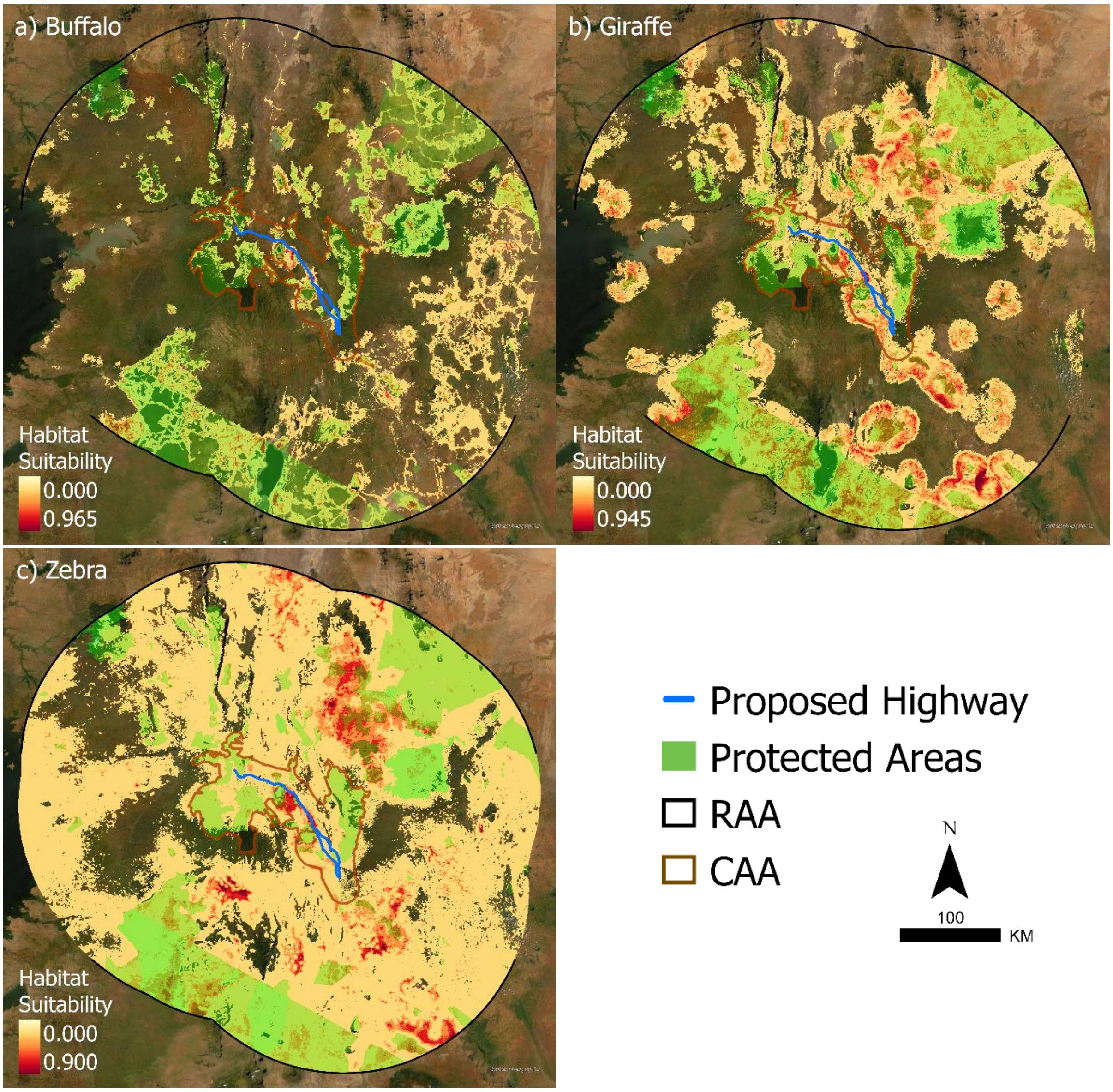
Appendix G: Other Species Distribution Modelling Mapping Outputs

Species Distribution Modelling Outputs with protected areas



Species distribution modelling habitat suitability output; (a) Buffalo, (b) Giraffe and (c) Zebra

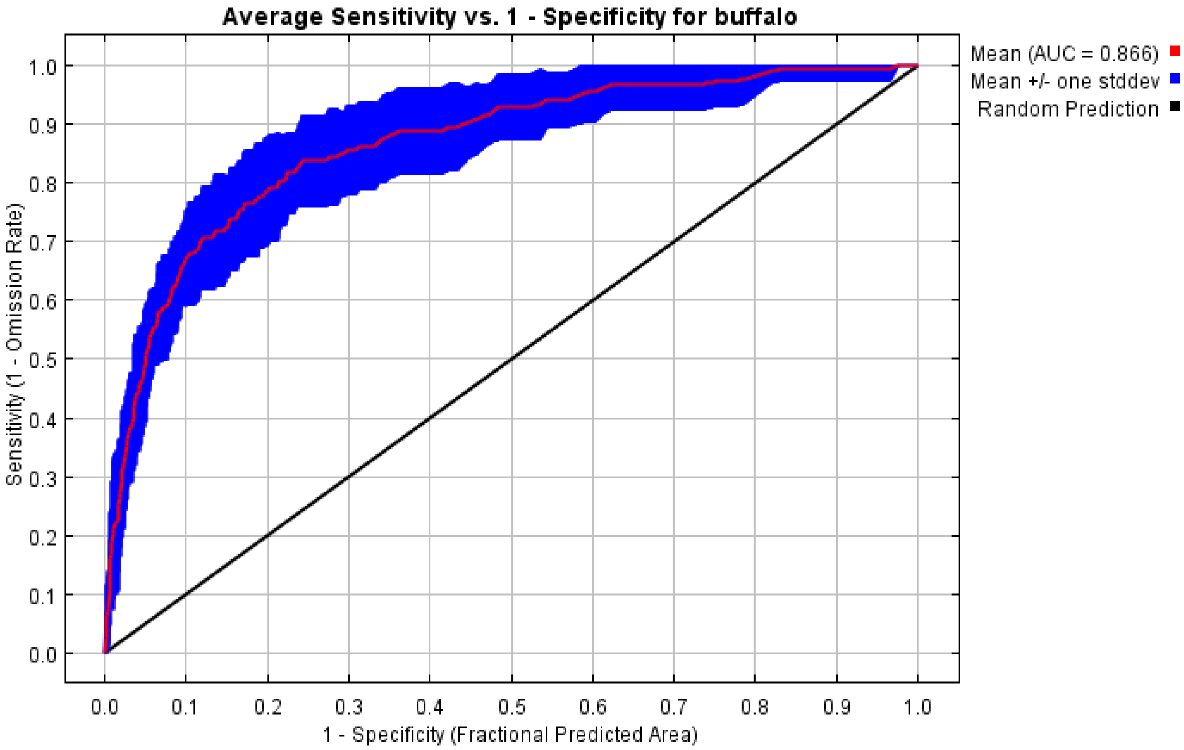
Species Distribution Modelling Outputs with satellite Imagery and protected areas



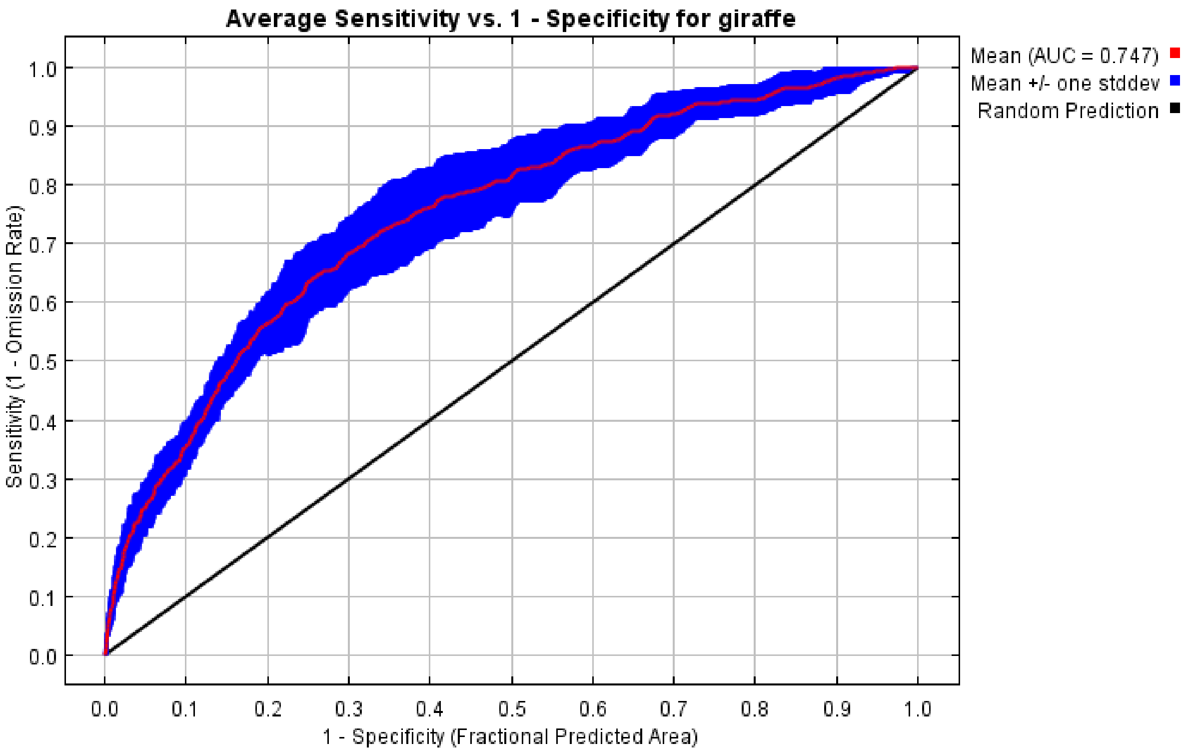
Species distribution modelling habitat suitability output; (a) Buffalo, (b) Giraffe and (c) Zebra

Appendix H: MaxEnt receiver operating characteristic (ROC) curves

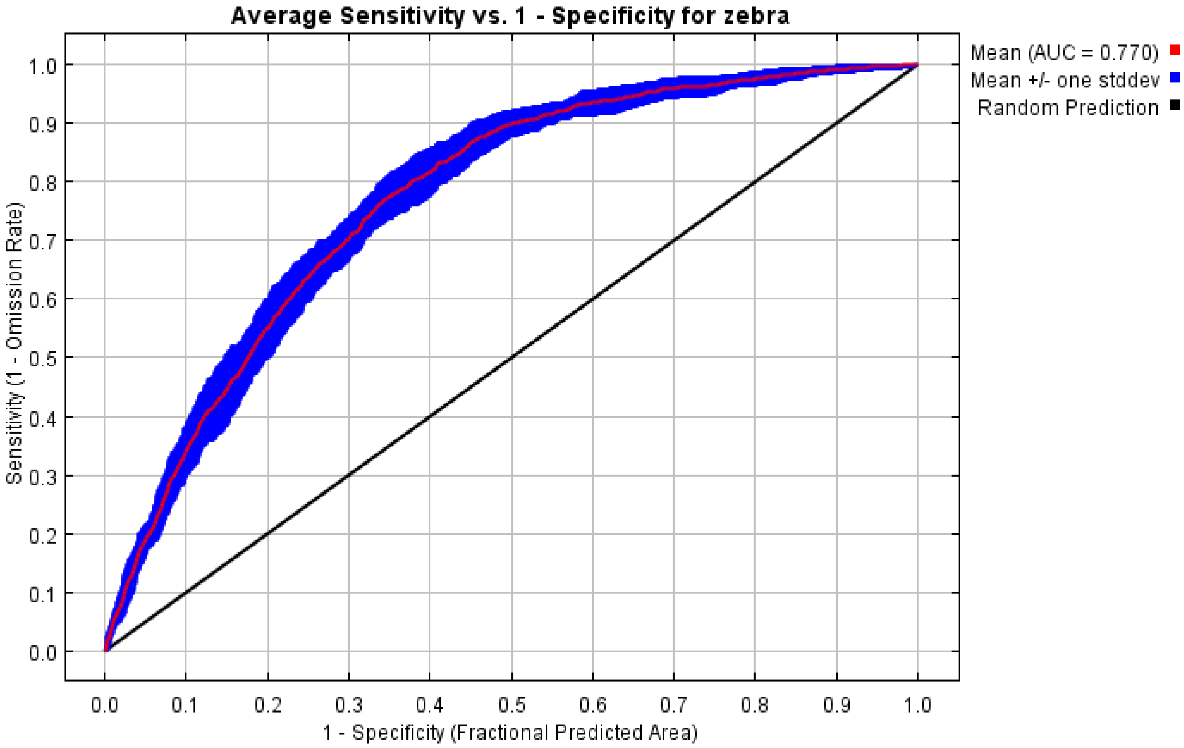
The receiver operating characteristic (ROC) curve for Buffalo, averaged over the replicate runs. Note that the specificity is defined using predicted area, rather than true commission



The receiver operating characteristic (ROC) curve for Giraffe, averaged over the replicate runs. Note that the specificity is defined using predicted area, rather than true commission

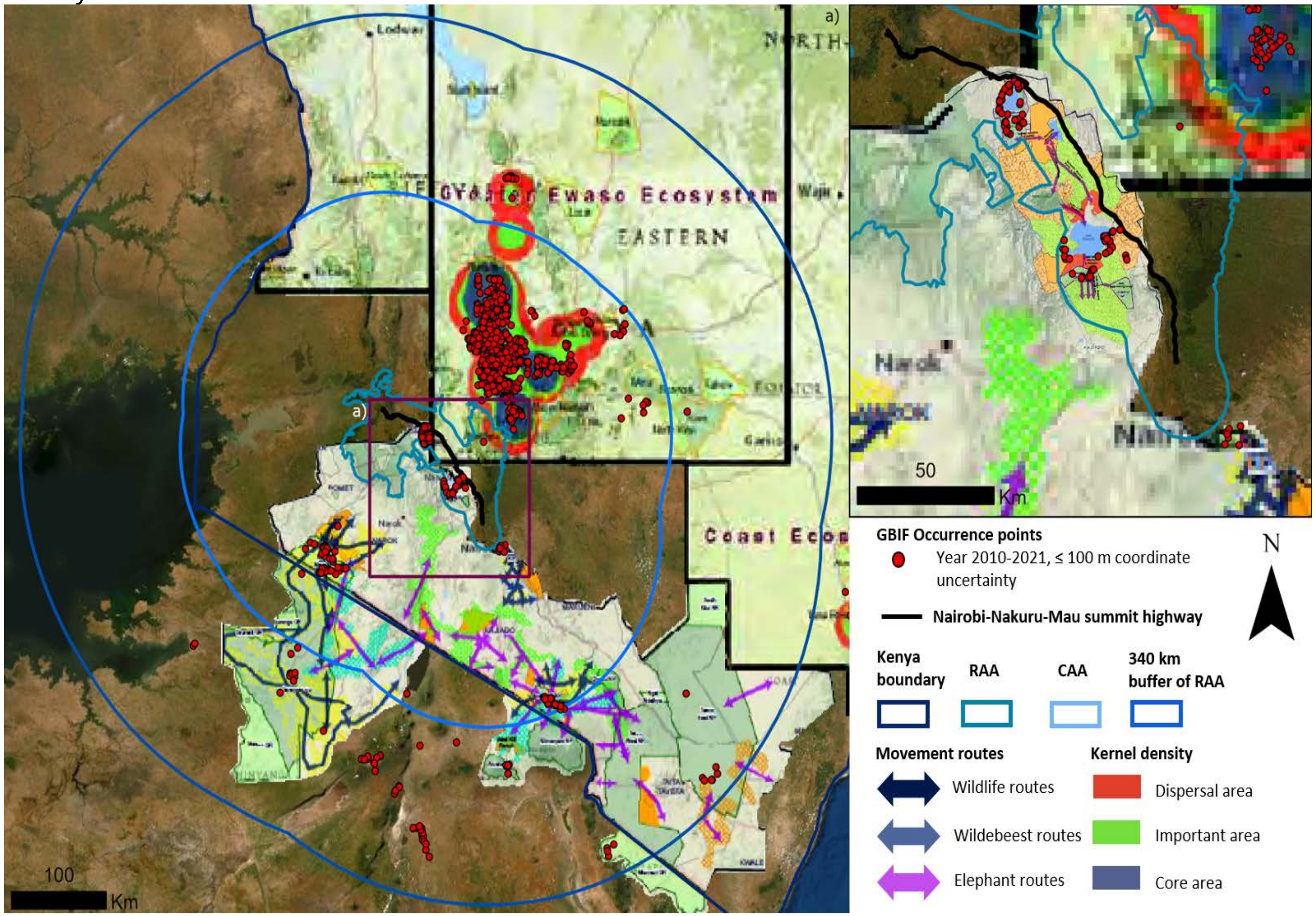


The receiver operating characteristic (ROC) curve for Zebra, averaged over the replicate runs. Note that the specificity is defined using predicted area, rather than true commission

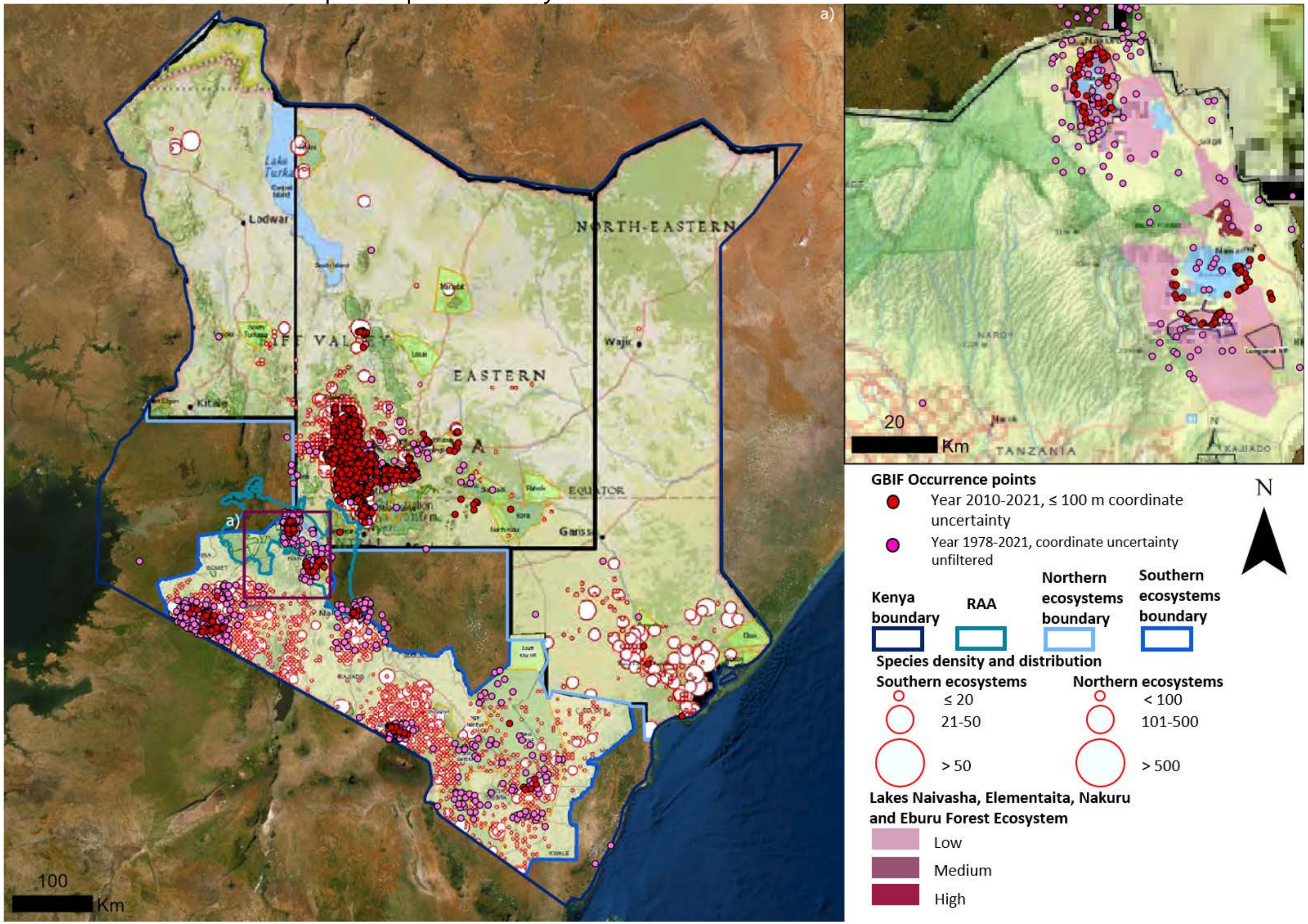


Appendix I: Comparison of occurrence points to existing mapping by Ojwang' et al., 2017

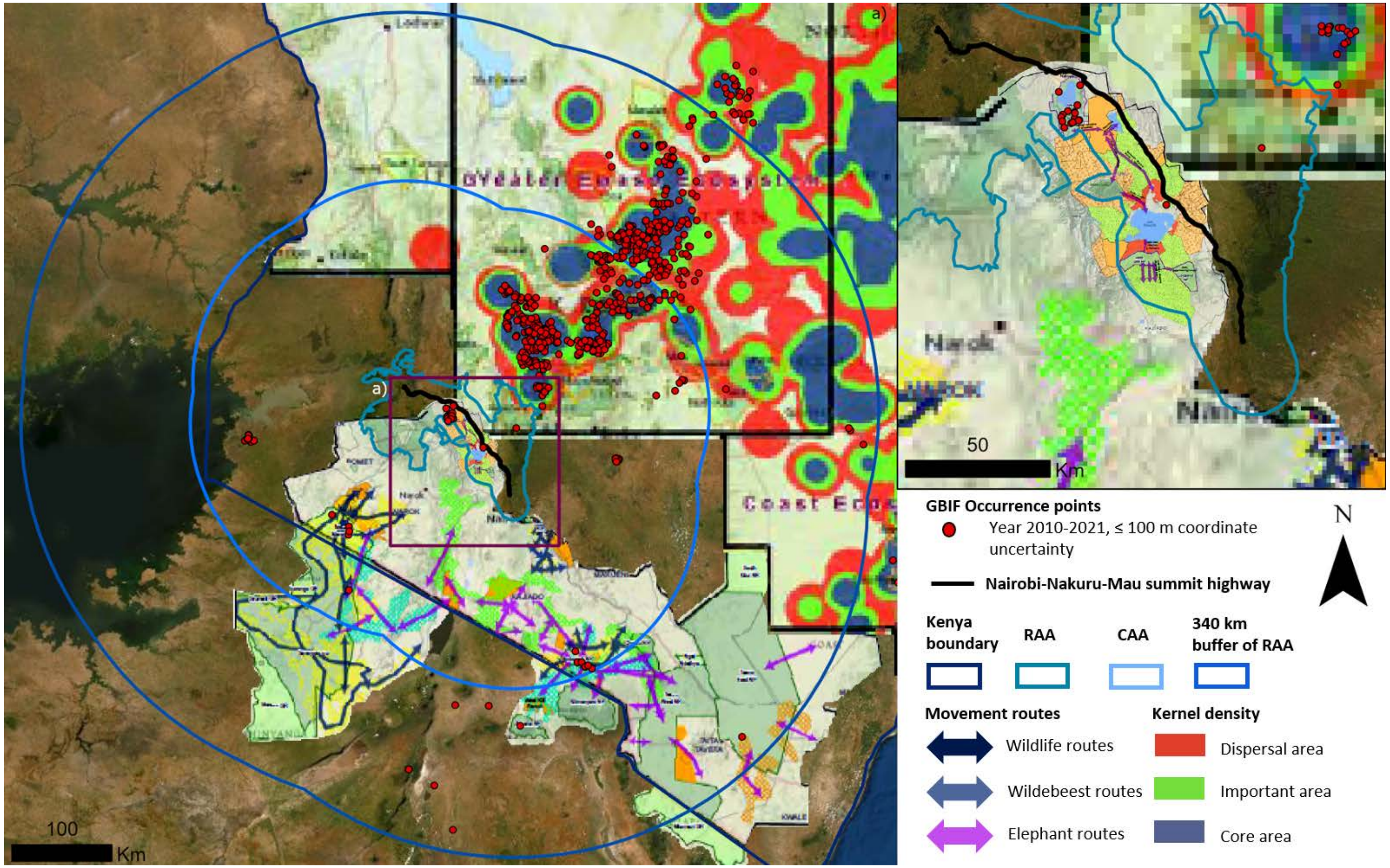
Movement routes and Plains zebra kernel densities from Wildlife Migratory Corridors and Dispersal Areas report (Ojwang' et al., 2017) overlayed with GBIF occurrence data



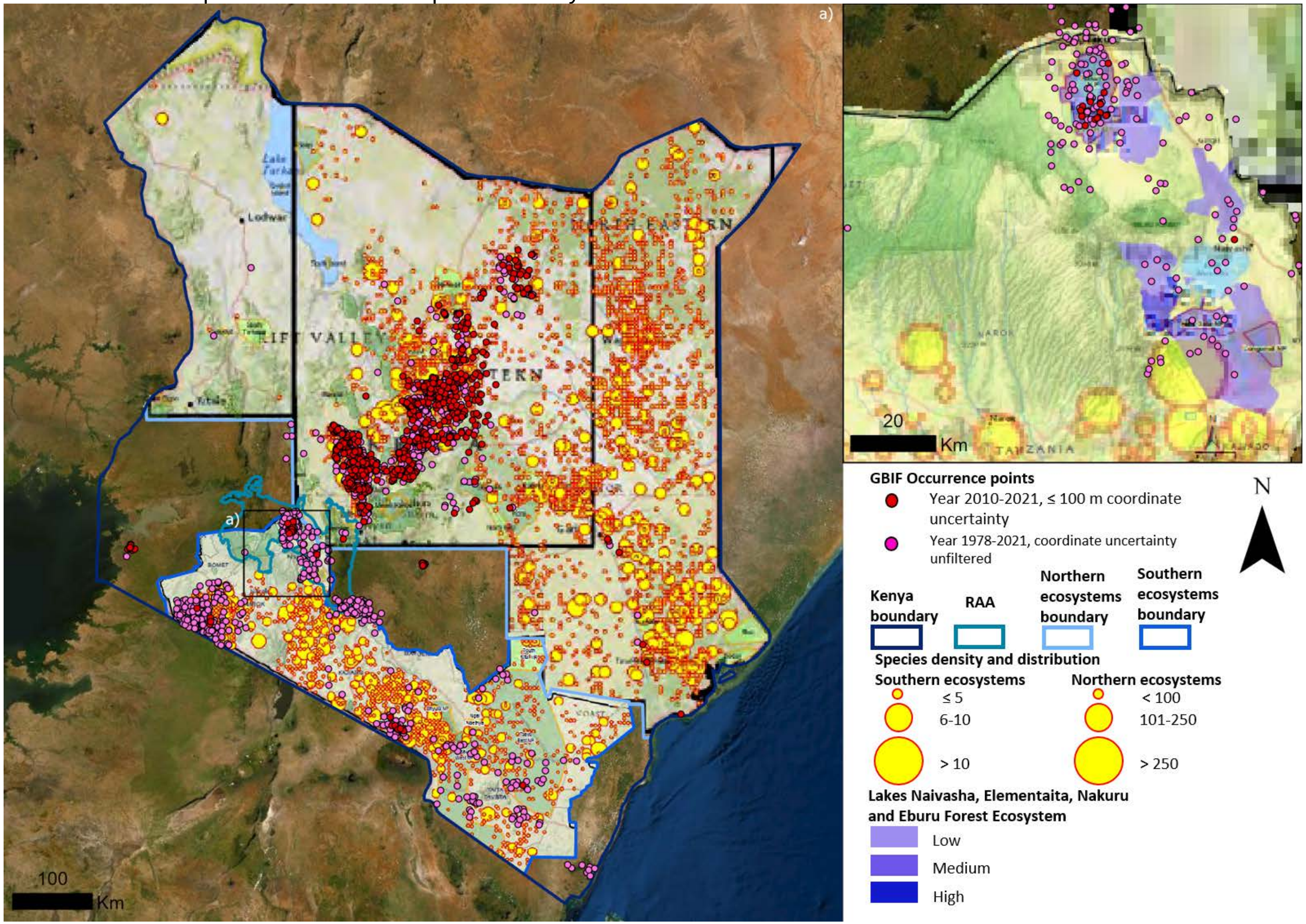
Plains zebra GBIF occurrence points species density and distribution based on field data



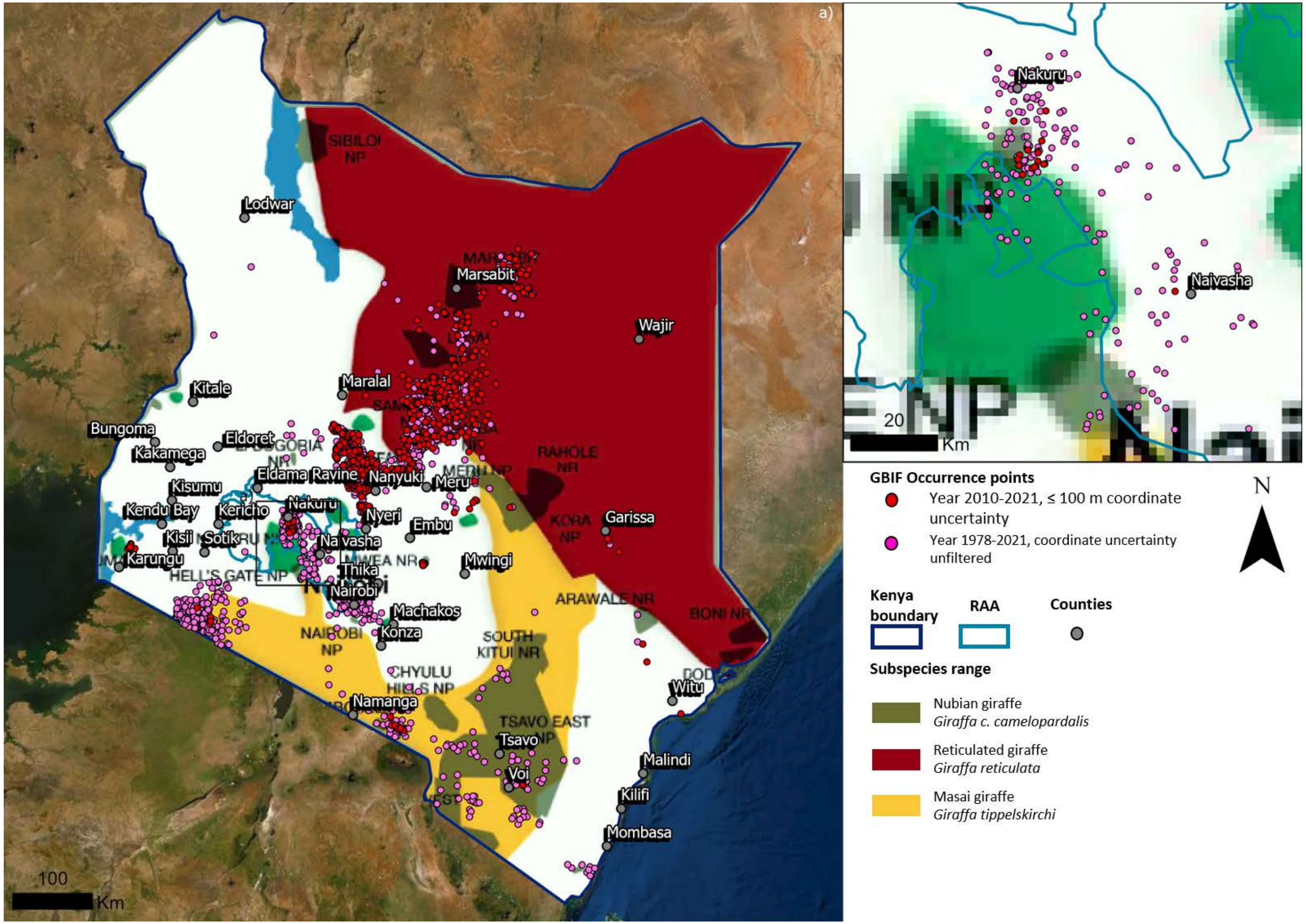
Occurrence data and movement routes and Giraffe kernel densities



Giraffe occurrence point from GBIF and species density and distribution based on field data



Appendix J: Comparison of Giraffe occurrence points to Giraffe subspecies mapping



APPENDIX

6-21 *FRESHWATER ECOLOGY BASELINE STUDY*

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

Freshwater Ecology Baseline Study
FINAL REPORT

Report Compiled by:

Gina Walsh, *Pr. Sci. Nat*
Marco Alexandre, *Pr. Sci. Nat*

July 2021

Document history

Version	**Reviewed by**	**Requests noted**
Draft V1	Jerome Gaugris, *Pr. Sci. Nat.*	
Draft V1	Maya Brennan Jacot - WSP	
FINAL version	Gina Walsh, *Pri.Sci.Nat.* Marco Alexandre, *Pri.Sci.Nat.* Phoebe Mottram, *Cand.Sci.Nat* Jerome Gaugris, *Pri.Sci.Nat.*	

Executive Summary

Introduction

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 proposed expansion of the Rironi-Mau Summit Highway in Kenya involves the dualling of 175 km of the A8 highway from Rironi to Mau Summit, as well as the strengthening of A8-South Highway between Rironi and Naivasha (57.2 km)

The ESIA is undertaken 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 – the Consultants) 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 present document provides the baseline results of the work undertaken with respect to the freshwater ecology.

Methodology

A literature review and desktop assessment were undertaken of the larger catchment area to establish an understanding of the prevailing study areas conditions. Emphasis was placed on environmental drivers and biological responders. The fieldwork consisted of assessing several pre-selected sites for the following components:

- **Water quality**: *In situ* analysis and analysis of major ions that are important for the maintenance of ecological integrity;
- **Habitat integrity (quality)**: Impacts on riparian and instream habitat integrity were evaluated at a catchment level and included on a site level basis in the various appendices;
- **Habitat availability** for fishes and macroinvertebrates was assessed at a catchment level and data for monitoring is included at a site level in the appendices;
- **Diatoms:** the present diatom assemblages and the spatial variation per catchment in diatom assemblages were determined. Subsequent inferences of baseline ecological water quality preferences per site and catchment were made based on diatom species' ecological water quality preferences;
- **Aquatic macroinvertebrate assemblages:** Emphasis was placed on the presence of sensitive taxa (the % of Ephemeroptera-Plecoptera-Trichoptera) and the presence of snail species at sites due to the potential presence of *Bulinus permembranaceus*, which is a Vulnerable species of concern noted in the Critical Habitat Assessment for the Project ;
- **Fish assemblage assessments** were undertaken at sites and per catchment. The fish assessment included the assessment of all fish species according to thresholds in the IFC Performance Standard 6 for Criteria 1 to 3. Fish community and diversity analyses were also included per catchment.

Summary of Key Findings

- The findings of the report indicate that the systems in the study area are in a transformed state with overall low freshwater sensitivity.
- The Yala, Molo and Lake Naivasha catchments classify as Modified Habitat as per IFC PS6 and the developer should implement mitigation to manage impacts for the construction of the road and demonstrate the implementation of the Mitigation Hierarchy.
- Lake Elementeita, Rift Valley and Aberdares catchments are assessed as as Natural Habitat and need to attain No Net Loss to achieve biodiversity targets.
- No Critical Habitat qualifying features were noted for Criterion 1, 2 and 3 for the freshwater systems along the road alignment.

Catchment	Habitat Classification (IFC PS6)
Yala River	Modified Habitat
Molo River	Modified Habitat
Lake Nakuru	Modified/Natural Matrix
Lake Elementeita	Natural Habitat
Lake Naivasha	Modified Habitat
Rift Valley	Natural Habitat
Abedares	Natural Habitat

Conclusion

The findings of the freshwater baseline show that the area is in a moderately to largely transformed state overall, with a low freshwater sensitivity. No freshwater Critical Habitat qualifying features are present in the study area, and the area is comprised of a matrix of Natural and Modified Habitat. All fish species identified in the study area are widespread in the Freshwater Ecoregion, with a large component of the community comprising of exotic species.

The proposed nature of the road upgrade would likely have a high impact in the direct project footprint of the road construction zone, however, this will dissipate relatively quickly downstream if the correct mitigation measures are put in place to control sediment inputs, decrease water quality impacts, and maintain freshwater connectivity. It is also considered feasible to reinstate the rivers to their pre-existing condition to attain NNL in sections of Natural Habitat. Whilst the impact is high on the aquatic systems, the duration is relatively short and the options for reinstatement are good, so the impacts can be mitigated so that no residual impacts exist after the reinstatement of the freshwater systems to pre-construction conditions that are highlighted within this baseline report.

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Appendix A-1	-	Sites and Methods Applied
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List of Abbreviations

%EPT	Percentage of Ephemeroptera-Plecoptera-Trichoptera
%PTV	Percentage Pollution Tolerant Valves
AEV	Acute Effect Values
ASPT	Average Score per Taxa
AVG	Average
CEN	Comité Européen de Normalisation
CEV	Chromic Effects Values
CH	Critical Habitat
CHA	Critical Habitat Assessment
CR	Critically Endangered
EC	Electrical Conductivity
EN	Endangered
EN	Endangered
ESIA	Social Impact Assessment
FFMES	Flora Fauna & Man Ecological Services Ltd.
GIS	Geographical Information System
GSM	Gravel-Sand-Mud
IFC PS6	International Finance Corporation Performance Standard 6
IHAS	Invertebrate Habitat Assessment System
IHI	Index of Habitat Integrity
IUCN	International Union for the Conservation of Nature
LC	Least Concern
LC	Least Concern
MH	Modified Habitat
NG	Net Gain
NH	Natural Habitat
NMDS	Non-Metric Multidimensional Scaling
NNL	No Net Loss
PCA	Principal Component Analysis
RVHL	Rift Valley Highway Limited
SADI	South African Diatom Index
SANAS	South African National Accreditation System
SASS5	South African Scoring System (version 5)
SIC	Stones-In-Current
SOOC	Stones-Out-Of-Current
SPI	Specific Pollution sensitivity Index
STDev	Standard Deviation
TDS	Total Dissolved Solids
Temp	Temperature
TWQRs	Target Water Quality Ranges
VEG	Vegetation
VU	Vulnerable

1. Introduction

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 proposed expansion of the Rironi-Mau Summit Highway in Kenya involves the dualling of 175 km of the A8 highway from Rironi to Mau Summit, as well as the strengthening of A8-South Highway between Rironi and Naivasha (57.2 km)

The ESIA is undertaken 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 – the Consultants) 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 present document provides the baseline results of the work undertaken with respect to the freshwater ecology.

This work was undertaken by the following team members:

- Lead freshwater ecologist: Gina Walsh
  - Degrees: MSc Aquatic Health from the University of Johannesburg, PhD candidate in Ecology from the University of the Witwatersrand, Johannesburg, South Africa
  - Professional accreditation: SACNASP *Pr. Sci. Nat* (400192/10)
  - N° of years of experience: 15 years' experience
  - Publications in field: 7 publications
  - Prior experience in Kenya / region: Kenya, Uganda, Tanzania, Ethiopia

- Freshwater ecologist: Marco Alexandre
  - Degrees: MSc Aquatic Health from the University of Johannesburg, Johannesburg, South Africa
  - Professional accreditation: SACNASP Pr. Sci. Nat (400079/13)
  - N° of years of experience: 13 years' experience
  - Publications in field: 4 publications
  - Experience in Kenya / Region: Kenya, Uganda

2. Scope of Work

The Consultants were responsible for compiling a freshwater specialist report focused on setting a baseline condition for the Nairobi-Nakuru-Mau Summit Highway Project Biodiversity Local Assessment Area (from here on referred to as the study area). The area of interest pertains to the area of direct and indirect impacts encompassing a 2 km buffer on either side of the road, and the Project's direct area of influence which includes the widening of the A8.

The following parameters were assessed to ascertain the baseline state of the aquatic ecosystems in the study area over two survey seasons undertaken in February and April 2021:

- **Water quality**: *In situ* analysis and analysis of major ions that are important for the maintenance of ecological integrity;
- **Habitat integrity (quality)**: Impacts on riparian and instream habitat integrity were evaluated at a catchment level and included on a site level basis in the various appendices;
- **Habitat availability** for fishes and macroinvertebrates was assessed at a catchment level and data for monitoring is included at a site level in the appendices;
- **Diatoms:** the present diatom assemblages and the spatial variation per catchment in diatom assemblages were determined. Subsequent inferences of baseline ecological water quality preferences per site and catchment were made based on diatom species' ecological water quality preferences;
- **Aquatic macroinvertebrate assemblages:** Emphasis was placed on the presence of sensitive taxa (the % of Ephemeroptera-Plecoptera-Trichoptera) and the presence of snail species at sites due to the potential presence of *Bulinus permembranaceus*, which is a Vulnerable species (Van Damme & Lange, 2017) species of concern noted in the Critical Habitat Assessment for the Project (TBC, 2018);
- **Fish assemblage assessments** were undertaken at sites and per catchment. The fish assessment included the assessment of all fish species according to thresholds in the IFC Performance Standard 6 (IFC PS6 – IFC, 2012; IFC, 2019) for Criteria 1 to 3. Fish community and diversity analyses were also included per catchment.

3. Assumptions and Limitations

3.1. General

Data presented in this document may not elucidate all possible conditions that may exist given the limited nature of the enquiry and the poorly explored nature of this region.

The freshwater systems in the study area vary in terms of their natural hydrology. Some of the larger river systems (e.g. the Molo and Mereronai rivers) were flowing in both seasons and therefore the full suite of aquatic methods could be applied to these systems. Most other rivers are non-perennial streams that had very limited inundation or were not flowing at all. These system could not support the application of all aquatic methods due to the lack or limited presence of water.

The budget for the project included 22 laboratory water quality samples and 22 diatom samples for both seasons, which were taken at larger sites that were inundated in the various surveys and where the biggest impact is likely to occur in the construction phase. Details of methods applied per site can be found in Appendix A-1.

3.2. Macroinvertebrate Assessment

Whilst the South African Scoring System version 5 (SASS5) field sampling method was used to standardise the sampling effort between sites, the inference of classes was not undertaken due to geographical limitations. An Ephemeroptera-Plecoptera-Trichoptera (%EPT) index was instead used in this study. The %EPT was based on the percentage of EPT families present at each site in relation to the total number of families, as these families are generally sensitive and may be used for monitoring of changes to the environment during the construction phase of the project. Some sites could not be assessed completely due to low flow conditions. In such situations emphasis should be placed on other available response metrics such as diatoms or *in situ* water quality.

3.3. Legal

This report excludes a review of the legal implications for the proposed activity in relation to aquatic ecosystems. A professional legal opinion on this aspect of the development should be sought out.

4. Materials and Methods

4.1. Study Area

A desktop study was undertaken to determine applicable information with regards to the greater catchment area, associated Ecoregions, nature of the drainage systems and overall catchment utilisation. Two field surveys were carried out in February 2021 (dry season) and April 2021 (wet season), which included the assessment of 40 sampling sites for habitat integrity, water quality, diatoms, aquatic macroinvertebrates and fish to establish baseline conditions (Table 1 and

Figure 1 to

D	E	

Figure 5) Photos of each site are provided in **Appendix A**:

The study area was considered as the project's Local Assessment Area (i.e. 2km either side of the current road). Sites were selected based on the road alignment and areas of direct impact from road works. Sites were divided into different lotic[1] and lentic[2] habitat types according to their geographical situation, flow, channel geomorphology and topography. No sites were sampled in the Nakuru catchment as all rivers were dry or completely destroyed due to the presence of Nakuru Town and existing road infrastructure in this catchment. Site naming convention for the freshwater sites is as follows:

The **prefix** of site name represents the **sub-catchment** where the site was located:

- Y Yala
- M Molo
- E Elementeita
- N Naivasha
- R Rift Valley
- A Aberdares

The **suffix** of the site name represents the freshwater **habitat type** sampled:

- R Rivers
- S Perennial streams
- NP Non-perennial streams
- W Wetlands

As an example, site Y1_NP is a site in the Yala River (Y) sub-catchment with the unique site code (1) and is a non-perennial stream (NP)

[1] Situated in moving freshwater.
[2] Situated in still freshwater.

Table 1: Coordinates and descriptions of sites sampled in the Nairobi-Nakuru-Mau Summit Highway Project Freshwater Ecology Baseline Study in February and April 2021

Site	Latitude	Longitude	River System and sub-catchment	Habitat type	Grid No. (As per FFMES sample design)
Yala River					
Y1_NP	35.6665	-0.1364	Headwater tributary of Yala River	Non-perennial stream	Z22
Y2_NP	35.6765	-0.1375	Headwater tributary of Yala River	Non-perennial stream	AA22
Molo River					
M1_NP	35.6899	-0.1571	Molo River tributary	Non-perennial stream	AB23
M2_S	35.6958	-0.1760	Molo River tributary	Perennial stream	AB24
M3_S	35.7703	-0.2255	Molo River	Perennial stream	AF27
M4_S	35.7203	-0.1985	Molo River tributary	Perennial stream	AC26
M5_R	35.7342	-0.2239	Molo River	River	AD27
M6_R	35.8346	-0.1973	Molo River	River	AK26
M7_S	35.8710	-0.2167	Molo River tributary	Perennial stream	AM27
M8_NP	35.8881	-0.2255	Molo River tributary	Non-perennial stream	AN27
M9_S	35.8648	-0.2146	Rongai River	Perennial stream	AL27
M10_W	35.7099	-0.1791	Molo River tributary	Wetland	AC25
M11_S	35.7853	-0.2052	Molo River tributary	Perennial stream	AG26
M12_NP	35.8004	-0.2056	Small dam	Non-perennial stream	AH26
Lake Elementeita					
E1_S	36.2034	-0.3617	Mereronai River	Perennial stream	BF35
E2_S	36.2150	-0.3756	Mbaruk River	Perennial stream	BG35
E3_NP	36.2529	-0.4098	Lake Elementeita tributary	Non-perennial stream	BJ37
E4_S	36.2758	-0.4552	Lake Elementeita tributary	Perennial stream	BK40
E5_NP	36.2838	-0.4675	Lake Elementeita tributary	Non-perennial stream	BL41
E8_S	36.2130	-0.3938	Mereronai River	Perennial stream	BG36
E8_NP	36.2296	-0.3909	Lake Elementeita tributary	Non-perennial stream	BH36
E10_S	36.2221	-0.3966	Mereronai River	Perennial stream	BG37

Site	Latitude	Longitude	River System and sub-catchment	Habitat type	Grid No. (As per FFMES sample design)
Lake Naivasha					
N1_S	36.3623	-0.5898	Morendat River	Perennial stream	BQ47
N2_R	36.3788	-0.6750	Malewa River	River	BR52
N3_S	36.4105	-0.6891	Karate River	Perennial stream	BT53
N4_S	36.5184	-0.7952	Malewa tributary	Perennial stream	BZ59
N5_NP	36.5400	-0.8204	Malewa tributary	Non-perennial stream	CA60
N6_NP	36.4788	-0.7585	Malewa tributary	Non-perennial stream	BX57
N7_NP	36.5076	-0.7715	Malewa tributary	Non-perennial stream	BY57
N8_NP	36.5491	-0.8273	Malewa tributary	Non-perennial stream	CB60
Rift Valley					
R1_S	36.6018	-1.0298	River draining to Rift Valley	Perennial stream	CE72
R2_S	36.6035	-1.0205	River draining to Rift Valley	Perennial stream	CE71
R3_S	36.5942	-0.9890	River draining to Rift Valley	Perennial stream	CC68
R4_S	36.5782	-0.9754	River draining to Rift Valley	Perennial stream	CA69
Aberdares					
A1_S	36.6079	-0.9161		Perennial stream	CE65
A2_S	36.6313	-0.9542	Bathi River	Perennial stream	CF67
A3_W	36.6365	-0.9989		Wetland	CF70
A4_W	36.6474	-1.0394	Valley bottom wetland	Wetland	CG72
A5_W	36.6330	-1.1034		Wetland	CE65
A6_S	36.6156	-0.9324		Perennial stream	CE66

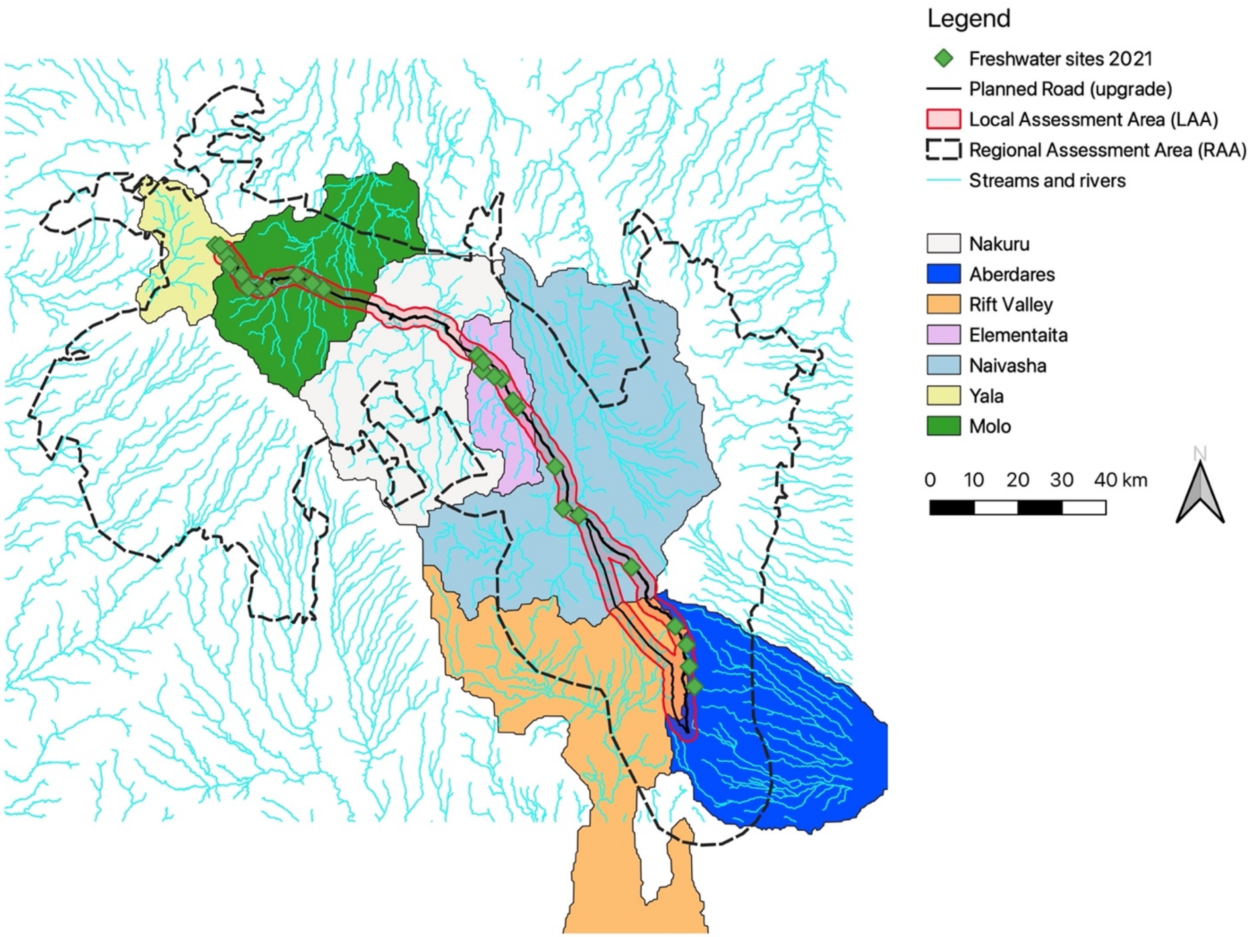


Figure 1: Extent of the study area and spatial distribution of sites for the Nairobi-Nakuru-Mau Summit Highway Project freshwater biodiversity study.

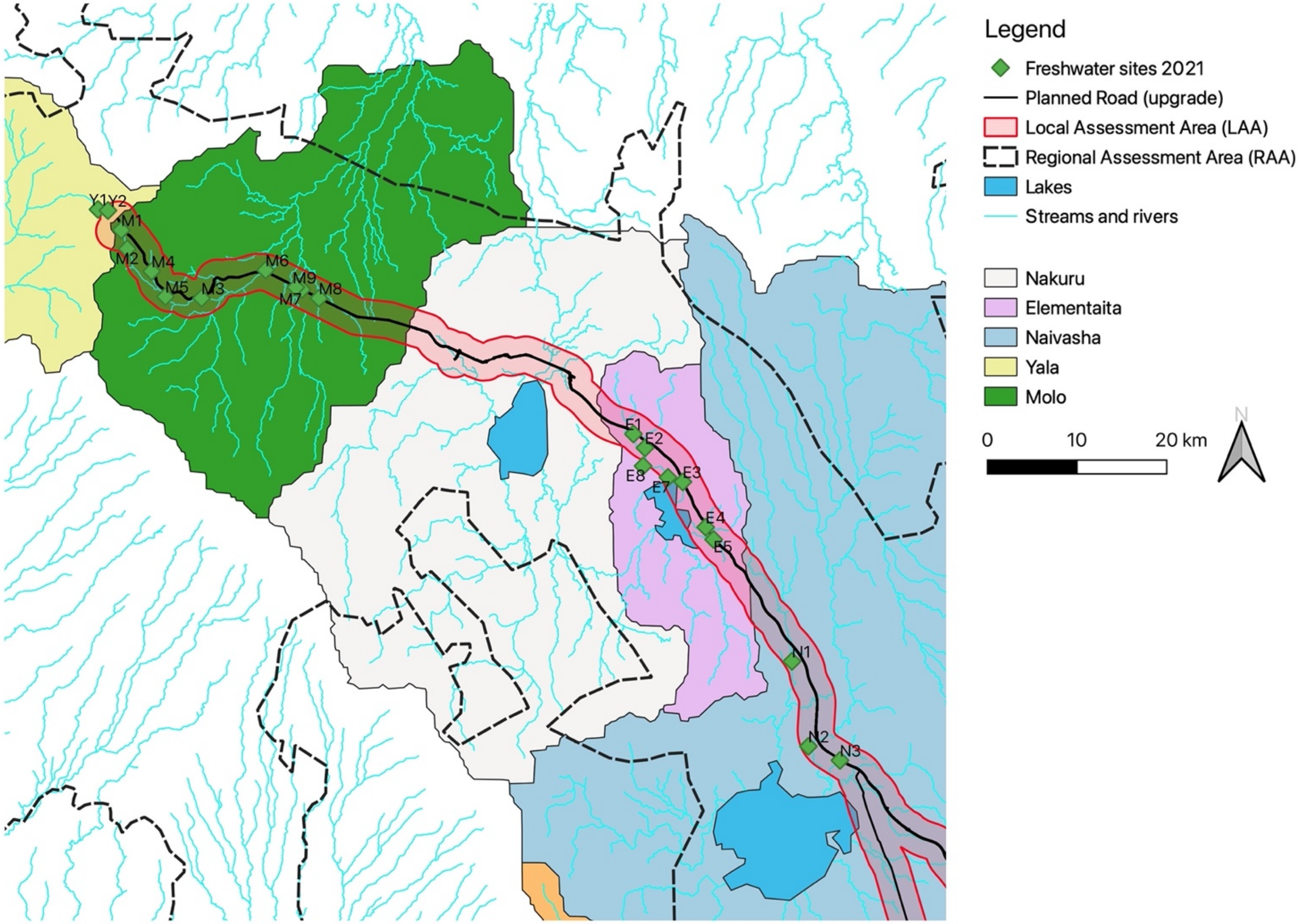


Figure 2: Extent of the study area and spatial distribution of sites for the Nairobi-Nakuru-Mau Summit Highway Project freshwater biodiversity study situated in the Yala to Elementeita catchments.

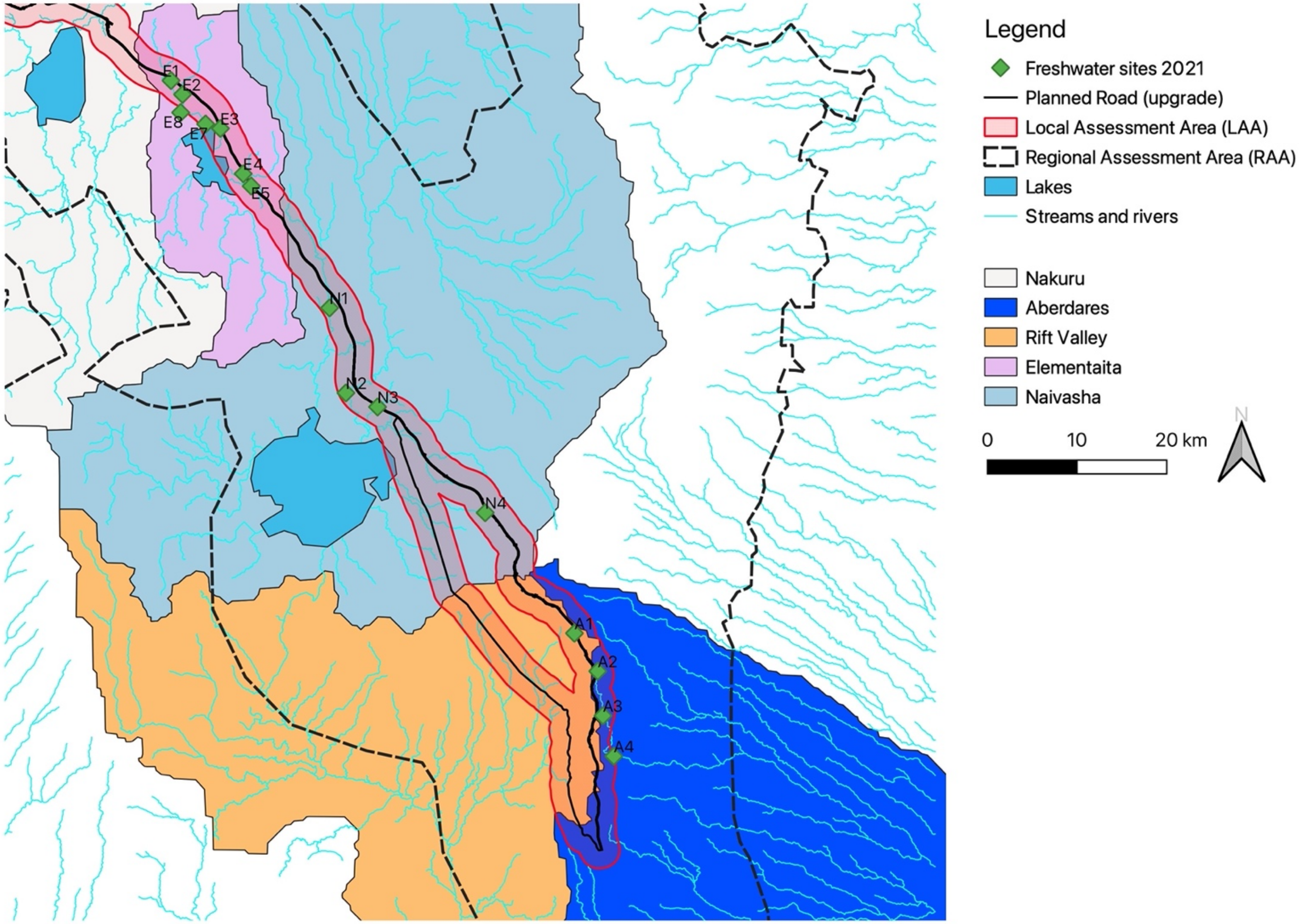


Figure 3: Extent of the study area and spatial distribution of sites for the Nairobi-Nakuru-Mau Summit Highway Project freshwater biodiversity study situated in Elementeita to Aberdares catchments.

4.2. Field Assessment and data analysis

4.2.1. Water Quality Assessment

The *in situ* physico-chemical variables that were measured during the aquatic surveys are shown in Table 2. *In situ* analysis was undertaken using a pre-calibrated Eutech multi-parameter water quality meter.

Table 2: *In situ* parameters measured during the field assessments.

In situ parameters	Abbreviation	Units
pH	pH	H^1+ ions
Temperature	Temp	°C
Electrical Conductivity	EC	µS/cm
Total Dissolved Solids	TDS	ppm
Turbidity	Turb	NTU

Water samples were collected at 11 sites (Section 5.3.1) during the February and April 2021 survey, cooled and transported to South Africa for laboratory analyses. Major ions and nutrients were measured, along with heavy metal contents, for hydro-chemical characterisation (Table 3). Water quality analysis was undertaken by a South African (SANAS) accredited laboratory. Please refer to **Appendix B** for laboratory results of the water quality analyses. Hydro-chemical characterisation was undertaken using AqQa software where values were plotted and major anions and cations were projected in a Piper Diagram - a multifaceted plot wherein milliequivalents percentage concentrations of major cations (Ca2+, Mg2+, Na+ and K+) and anions (HCO3-, SO4 2-, and Cl-) are plotted in two triangular fields, which are then projected further into the central diamond field, to ascertain baseline water types.

Table 3: Laboratory water quality values measured at sites.

Analyte Name	Units
Sum of Anion Milliequivalents	meq/l
Sum of Cation Milliequivalents	meq/l
Anion-Cation Balance	%
Acidity as CaCO3	mg/l
Total Alkalinity as CaCO3	mg/l
Calcium	mg/l
Iron	mg/l
Potassium	mg/l
Magnesium	mg/l
Sodium	mg/l
Tellurium	mg/l
Aluminium	mg/l
Arsenic	mg/l
Boron	mg/l
Barium	mg/l
Beryllium	mg/l
Cadmium	mg/l
Cobalt	mg/l
Chromium	mg/l
Copper	mg/l
Manganese	mg/l

Analyte Name	Units
Molybdenum	mg/l
Lead	mg/l
Nickel	mg/l
Antimony	mg/l
Selenium	mg/l
Strontium	mg/l
Thorium	mg/l
Titanium	mg/l
Thallium	mg/l
Uranium	mg/l
Vanadium	mg/l
Zinc	mg/l
Zirconium	mg/l
Chloride	mg/l
Fluoride	mg/l
Nitrite	mg/l
Nitrite as N	mg/l
Nitrate	mg/l
Nitrate as N	mg/l
Sulphate	mg/l
Mercury	µg/l
Ammonia	mg/l
Ammonia as N	mg/l

Water quality data for major ions were compared to benchmark criteria compiled by Kotze (2002) consisting of Target Water Quality Ranges (TWQRs - DWAF, 1996) and source water quality guidelines set by Rand Water (Steynberg *et al.*, 1996; Rand Water, 1998) (Table 4 -Table 6). Heavy metal concentrations were compared to TWQRs for freshwater ecosystems (DWAF, 1996) (Table 6).

Table 4: Benchmark criteria for Ideal, Tolerable and Intolerable values for major ions (Kotze, 2002)

Parameter	Ideal mg/L	Tolerable mg/L	Intolerable mg/L
Ca	<150	-	>150
Cl	<50	50-150	>150
Mg	<70	-	>70
Na	<50	50-100	>100
SO_4	<80	80-500	>500
EC	<450*	450 - 1000*	>1000*
pH	6.5-8.5#	5-6.5 & 8.5-9#	<5 & >9#

* = µS-cm^{-1}; # = [H^1+ ions]

Table 5: Target Water Quality Guideline (TWQG) values (mg/l), with Chronic (CEV) - and Acute Effect values (AEV) (DWAF, 1996)

Const. Abr.	Criteria	TWQG	CEV[3]	AEV [4]
Al	pH<6.5	0.005	0.01	0.1
	pH>6.5	0.01	0.02	0.15
As	**-**	0.01	0.02	0.13
Cd	CaCO3<60mg/l	0.00015	0.0003	0.003
Cr (3)	-	0.012	0.024	0.34
Cr (6)	-	0.007	0.014	0.2
Cu	CaCO3<60mg/l	0.0003	0.00053	0.0016
Fe	The iron concentration should not be allowed to vary by more than 10 % of the background dissolved iron concentration for a particular site or case, at a specific time.			
Mn	-	0.18	0.31	1.3
Se	-	0.002	0.005	0.03
Hg	-	0.00004	0.00008	0.0017
Zn		0.002	0.0036	0.036

Table 6: Trophic status classification as represented by the TWQGs (mg/l) for aquatic ecosystems (DWAF, 1996)

Const. Abr.	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic
N (inorganic)	<0.5	0.5-2.5	2.5-10	>10

[3] CEV = is defined as "that concentration or level of a constituent at which there is expected to be a significant probability of measurable chronic effects to up to 5 % of the species in the aquatic community" (DWAF, 1996).
[4] AEV= is defined as "that concentration or level of a constituent above which there is expected to be a significant probability of acute toxic effects to up to 5 % of the species in the aquatic community" (DWAF, 1996).

4.2.2. Habitat Assessment

Habitat Integrity

The intermediate Index of Habitat Integrity (IHI) was applied on a site level basis to ascertain the change of instream and riparian habitat from natural conditions (Kemper, 1999). The habitat integrity assessment provides a tool for assessing instream and riparian habitat by incorporating factors and potential impacts (Kleynhans, 1996). The severity of impact of the modifications is based on six categories. These categories comprise of ratings ranging from 0 to 25: where the following is applicable: 0 (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact –Table 7).

Table 7: Descriptive classes for the assessment of modifications to habitat integrity (adapted from Kleynhans, 1996)

Impact Category	Description	Score
None	No discernible impact or the modification is in such a way that it has no impact on habitat quality, diversity, size, and variability.	**0**
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size, and variability are also exceedingly small.	**1 - 5**
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size, and variability are also limited.	**6 - 10**
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size, and variability. Large areas are, however, not influenced.	**11 - 15**
Serious	The modification is frequently present and the habitat quality, diversity, size, and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	**16 - 20**
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size, and variability in almost the whole of the defined section are influenced detrimentally.	**21 - 25**

The IHI assessment is based on two different components of riverine systems, namely, the riparian zone and instream channel. Separate assessments are done for both aspects; however, the data for the riparian zone is primarily interpreted in terms of the potential impact on the instream component (Kemper, 1999). The rating system is based on differing weights for each criterion

Table 8).

Table 8: Criteria and weights used for the assessment of habitat integrity (adapted from Kleynhans, 1996)

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Water abstraction	14	Bank erosion	14
Water quality	14	Indigenous vegetation removal	13
Bed modification	13	Water abstraction	13
Channel modification	13	Water quality	13
Flow modification	13	Channel modification	12
Inundation	10	Exotic vegetation encroachment	12
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Inundation	11
Solid waste disposal	6		
TOTAL	**100**	**TOTAL**	**100**

The calculation of the IHI score for each variable was undertaken as follows (Kleynhans, 1996):

- Individual variable score = (Field score obtained / Maximum score achievable) X Weight
- Instream integrity score = (Sum of all variables) / 225 X 100
- Riparian integrity = (Sum of all variables) / 200 X 100
- Total IHI = (Instream + Riparian) / 2

The outcome of the IHI assessment was to place sites into categories based on their overall habitat integrity: ranging from “Natural” to “Critically Modified”. The raw data for the IHI can be found in **Appendix C**. The categories were based on the overall IHI % as shown in

Table 9.

A qualitative approach to mapping of Natural and Modified Habitat was applied using information available from various IHI. The qualitative approach used the IHI to designate Natural and Modified riverine habitats according to IFC PS6 (Modified Habitat and Natural Habitat -

Table 9).

A principal components analysis (PCA) was completed on the full IHI data matrix to determine clustering and variable importance where a higher value represents higher importance and most significant habitat impacts driving the state of aquatic biodiversity were noted in the assessment.

Table 9: Overall habitat integrity classes (adapted from Kleynhans, 1996)

Category	Description	Score (%)	IFC PS6 Habitat
A - Natural	Unmodified, Natural.	90-100	Natural
B - Largely Natural	Few modifications, small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89	
C - Moderately Modified	A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79	
D - Largely Modified	Large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59	Modified
E - Seriously Modified	The losses of natural habitat, biota and basic ecosystem functions are extensive.	20-39	
F - Critically Modified	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	<20	

Macroinvertebrate Habitat Availability

Macroinvertebrate habitat availability was assessed using the Invertebrate Habitat Assessment System version 2 (IHAS v.2) methodology (McMillan, 1998). The IHAS is a quantitative and comparable description of habitat availability for aquatic macroinvertebrates. The IHAS reflects the quantity, quality, and diversity of biotopes available for habitation by aquatic macroinvertebrates. The quantity and quality of various sampling biotopes were assessed in terms of potential habitat for invertebrates and were expressed as a percentage score. The scores for each biotope were then summed to give a total habitat score and class (Table 10). The IHAS, in this context, purely provides a relative measure of habitat availability between sites and does not reflect the ecological state of the system in any way. The raw data for the IHAS can be found in **Appendix D**.

Table 10: Invertebrate Habitat Assessment System ratings and categories (McMillan, 1998)

IHAS score %	Description	Category
>70 %	Habitat is more than adequate and able to support a diverse invertebrate fauna	Good
60-70 %	Habitat is adequate and able to support invertebrate fauna	Adequate
<60%	Habitat is limited and unable to support adverse invertebrate fauna	Poor

Fish Habitat

The fish habitat assessment followed the method as outlined by Kleynhans (2007). The assessment is site specific and takes into consideration the diversity of velocity-depth classes, and the occurrence of various cover types at each velocity-depth class. This habitat assessment forms part of the fish assessment and presents a means within which the actual fish data and frequency of occurrence of species can be understood and interpreted. The raw data for the fish habitat assessment can be found in **Appendix E**.

4.2.3. Diatom Assessment

Benthic diatoms (diatoms attached to substrate) were sampled in inundated systems according to the protocol of Taylor et al. (2005). Samples were preserved in the field using formaldehyde to prevent decomposition. Ecological water quality preferences for diatom species were used from Taylor et al. (2007).

Diatom laboratory procedures were undertaken according to the methodology described by Taylor et al. (2005). Diatom samples were prepared for microscopy by using the hot hydrochloric acid and potassium permanganate method. Approximately 300 to 400 diatom valves were identified and counted to produce semi-quantitative data for analysis. The raw data for the IHI can be found in **Appendix F**. Prygiel et al. (2002) found that diatom counts of 300 valves and above were necessary to make correct environmental inferences. The taxonomic guide by Taylor et al. (2007b) was consulted for identification purposes. Where necessary, Krammer & Lange-Bertalot (1986, 1988, 1991 a, b) were used for identification and confirmation of species identification. Environmental preferences were inferred from Taylor et al. (2007b) and various other literature sources as indicated in the discussion section to describe the environmental water quality at each site.

Ecological classification for water quality

The ecological classification for water quality according to Van Dam et al. (1994) and Taylor *et al.* (2007), includes the preferences of diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state as provided by OMNIDIA (Lecointe et al., 1993).

Diatom-based water quality indices

There are different diatom-based water quality indices that are used globally and are based on the specific water quality tolerances of diatoms. Most of the indices are based on a weighted average equation by Zelinka & Marvan (1961). Two values are assigned to each diatom species used in the calculations of the indices that reflects the tolerance or affinity of the diatom species to a certain water quality (good or bad); and indicates how strong (or weak) the relationship is (Taylor, 2005). These values are then weighted by the abundance of the diatom species in the sample (Lavoie *et al.* 2006; Taylor, 2005; Besse, 2007). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta & Soininen 2002). These indices underpin the computer software packages used to estimate biological water quality. One such software package commonly used and approved by the European Union is OMNIDIA (Lecointe *et al.* 1993). The program is a taxonomic and ecological database of 7500 diatom species, and it contains indicator values and degrees of sensitivity for given species. It allows rapid calculations of indices of general pollution, saprobity and trophic state, indices of species diversity, as well as of ecological systems (Szczepocka, 2007).

The Specific Pollution Sensitivity Index (SPI)

The SPI was used in this diatom assessment (

Table 11) and is an inclusive index and takes factors such as salinity, eutrophication, and organic pollution into account (CEMAGREF, 1982). This index comprises 2,035 taxa (Taylor, 2005) and is recognised as the broadest species base of any index currently in use and has been adapted to include taxa endemic to and commonly found in South Africa, thus increasing the accuracy of diatom-based water quality assessments, and is known as the South African Diatom Index (SADI) (Harding & Taylor, 2011). The limit values and associated ecological water quality classes adapted from Eloranta & Soininen (2002), in conjunction with the new adjusted class limits that are provided in (Taylor & Koekemoer, in press), were used for interpretation of the SPI scores. The SPI index is based on a score between 0 – 20, where a score of 20 indicates no pollution and a score of zero indicates an increasing level of pollution or eutrophication.

Table 11: Adjusted class limit boundaries for the Specific Pollution Index in the evaluation of water quality applied in this study (adapted from Eloranta & Soininen, 2002; Taylor and Koekemoer, in press)

Interpretation of Index Scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High quality	18 - 20
A/B		17 - 18
B	Good quality	15 - 17
B/C		14 - 15
C	Moderate quality	12 - 14
C/D		10 - 12
D	Poor quality	8 - 10
D/E		6 - 8
E	Bad quality	5 - 6
E/F		4 - 5
F		< 4

The Percentage Pollution Tolerant Valves (%PTV)

The %PTV is part of the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) and was developed for monitoring organic pollution (sewage outfall- orthophosphate-phosphorus concentrations), and not general stream quality (Table 12). The %PTV has a maximum score of 100, where a score less than 20 indicates no organic pollution and a score of 100 indicates definite and severe organic pollution. The presence of more than 20% PTVs shows organic impact. All calculations were computed using OMNIDIA ver. 4.2 program (Lecointe et al., 1993).

Table 12: Interpretation of the percentage Pollution Tolerant Valves scores (adapted from Kelly, 1998)

%PTV	Interpretation
<20	Site free from organic pollution.
20 to <40	There is some evidence of organic pollution.
40 to 60	Organic pollution likely to contribute significantly to eutrophication.
>60	Site is heavily contaminated with organic pollution.

4.2.4. Macroinvertebrate Assessment

Aquatic macroinvertebrates were collected using the sampling protocol of the SASS5 method (Dickens & Graham, 2002). The protocol is divided between three biotopes, namely Vegetation (VEG), Stones-In-Current (SIC) and Gravel-Sand-Mud (GSM). Samples were collected in an invertebrate net with a pore size of 1000 microns on a 30 cm x 30 cm frame by kick sampling of SIC and GSM and sweeping of VEG for a standardised time or area. The deep-water sampling was limited to the VEG biotope as other biotopes were not available for sampling. Macroinvertebrates were identified to family level using relative reference guides (Dickens & Graham, 2002; Gerber & Gabriel, 2002). The raw data for the macroinvertebrate families can be found in **Appendix G**.

Macroinvertebrate community analyses

Univariate diversity and evenness indices were used to describe macroinvertebrate family-abundance relations using PRIMER version 7.0. The univariate analyses undertaken were the Shannon-Wiener diversity index (H'log$_e$), Pielou's evenness (J') and total number of species (S) and number of individuals per site.

The sensitivities of taxa as per Dickens & Graham (2002) and Mereta et al. (2013) were used to calculate Average Score Per Taxon (ASPT) and to make ecological inferences based on the macroinvertebrate community per site.

Average diversity per catchment type was calculated to compare between the macroinvertebrate communities. The ASPT values were used to make ecological inferences based on the macroinvertebrate communities per site, and average ASPT values were used to compare between the various catchments (Dickens & Graham, 2002).

Percentage of Ephemeroptera-Plecoptera-Trichoptera (%EPT)

Community data collected in the field was used to populate the Percentage Ephemeroptera-Plecoptera-Trichoptera (%EPT) based on the EPT method to assess macroinvertebrate integrity (MACS, 1996). This metric measures the abundance of the generally sensitive insect orders of Ephemeroptera-Plecoptera-Trichoptera Taxa from these orders are sensitive to environmental alterations and occur in clean and well oxygenated waters (Keci et al. 2012). The EPT assemblages are commonly considered to be good indicators of water quality (Rosenberg & Resh, 1993).

Potential Priority Species (Gastropoda)

The study area contains a large proportion of the range of *Bulinus permembranaceus*, a Vulnerable (Van Damme & Lange, 2017) restricted range species. The species is found in pools and small streams between 1940 to 2760 meters above sea level (masl) in the Aberdare Range, Kinangop Plateau and Mau Escarpment in Mau Narok, Molo and Kipkabus (Brown, 1994). Numerous suitable habitats were noted for the species in the form of perennial streams, specifically towards the northeast section of the road alignment during the scoping survey. As this species was highlighted as a potential priority species in the Critical Habitat Assessment (TBC, 2018), each freshwater site was physically searched for gastropod species for 20 minutes of effort by turning stones, sweeping through vegetation, and scraping bedrock and substrate to assess the presence of this species in the study area.

4.2.5. Fish Assessment

Sampling Effort

Where sites were inundated, sampling effort was site specific and based on habitat type and accessibility. Sampling techniques that were used included: (i) Electro-shocking and (ii) seine nets. Electro-shocking was undertaken at sites where conductivity was suitable. A description of the equipment used and the fish sampling effort per unit are listed in Table 13.

Table 13: Fish sampling equipment used, and the sampling effort followed during surveys.

Sampling type	Quantity	Sampling Effort	Mesh Size	Depth	Length/Size
Electro-shocking	1	40 min	N/A	N/A	NA
Small Seine Net	1	Pulls	30 mm	1 m	50 m

Fish Diversity Analysis

Univariate diversity and evenness indices were used to describe fish species-abundance relations using PRIMER version 7.0. The univariate analyses undertaken were the Shannon-Wiener diversity index ($H'log_e$), Pielou's evenness (J') and total number of species (S) and number of individuals per site.

Fish Community Analysis

Hierarchical clustering using the Bray-Curtis dissimilarity matrix via *vegan::vegdist::decostand* was used to determine differences in catchment level fish communities and contribution assessed using a permutational multivariate analysis of variance (PERMANOVA). A cluster dendrogram was used to visualise site similarity and a Principal Components Analysis (PCA) biplot used to identify which species are driving the clusters. The raw data for fish species sampled can be found in **Appendix H**.

Potential Priority Species (Fish)

Within the larger study area defined in the Critical Habitat Assessment (TBC, 2018), two freshwater fish species were noted that potentially meet the criteria of IFC's PS6 for Critical Habitat (TBC., 2018 - Table 14). Sampling was targeted in suitable habitats within the fish sampling surveys to assess the presence of these species in the study area under the direct influence of the Project.

Table 14: Critical Habitat-qualifying species identified in the broader study area (TBC, 2018)

Taxon	Species	IUCN Red List category (IUCN, 2021)	IFC PS6 Criterion (IFC, 2012)
Freshwater fish	*Lacustricola sp. nov. Baringo*	CR	1b
Freshwater fish	*Labeo victorianus*	CR	1c

4.2.6. IFC Performance Standard 6

IFC Performance Standard 6 (PS6) is considered as good international practice for biodiversity for development projects that seek alignment with leading biodiversity management practice (IFC, 2012). The objectives of PS6 are to protect and conserve biodiversity, maintain benefits from ecosystem services, and promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities.

PS6 requires projects to classify the area within which they operate into three categories: Modified Habitat (MH), Natural Habitat (NH) and Critical Habitat (CH) based on the extent of modification and the presence of high biodiversity values. This report considers species level criteria to assess the presence of CH, namely:

- Criterion 1: Critically Endangered and Endangered species;
- Criterion 2: Endemic/ Restricted Range species;
- Criterion 3: Migratory/Congregatory species.

The determination of CH for Criteria 1 to 3 is based on quantitative thresholds. Projects should encourage developments in areas of MH over NH, and NH over CH and should demonstrate the full application of the mitigation hierarchy framework to manage biodiversity impacts (avoid, minimise, restore, and when needed, offset) and must achieve a no net loss (NNL) of biodiversity in area of NH and a net gain (NG) in areas of CH.

IFC Guidance Note (GN6) provides guidance on how to identify MH, NH and CH based on thresholds (IFC 2019) which is summarised below.

Criterion 1: Critically Endangered and Endangered species

Areas qualifying for this criterion support:

a. Globally important concentrations of IUCN Red-listed Critically Endangered or Endangered species (>0.5% of the global population and >5 reproductive units of a CR or EN species).
b. Globally important concentrations of an IUCN Red-listed VU species, the loss of which would result in the change of the IUCN Red List status to EN or CR and meet the thresholds under (a); or
c. As appropriate, areas containing important concentrations of a nationally/regionally listed EN or CR species.

Criterion 2: Restricted-range species

Areas qualifying for this criterion hold ≥10% of the global population size and ≥10 reproductive units of a restricted-range species. " Restricted-range" refers to a species' extent of occurrence (EOO), and is defined according to its habitat:

- For terrestrial vertebrates and plants, a restricted-range species is a defined as those that have an EOO of less than 50,000 km^2.

- For riverine and other aquatic species in habitats that do not exceed 200 km width at any point (e.g., rivers), restricted range is defined as having a global range less than or equal to 500 km linear geographic span (i.e., the distance between occupied locations furthest apart). There are limited data on occupied locations of freshwater and marine species, and limited availability of those data. For freshwater species this was calculated by measuring the distance the two furthest points of the catchment(s) in which the species is present. To avoid underestimate the number of restricted-range species, since they may not occupy entire catchments within which they occur, careful consideration was given to freshwater species where linear geographic span was less than 600 km.

Criterion 3: Migratory and congregatory species

Areas qualifying for this criterion support either:

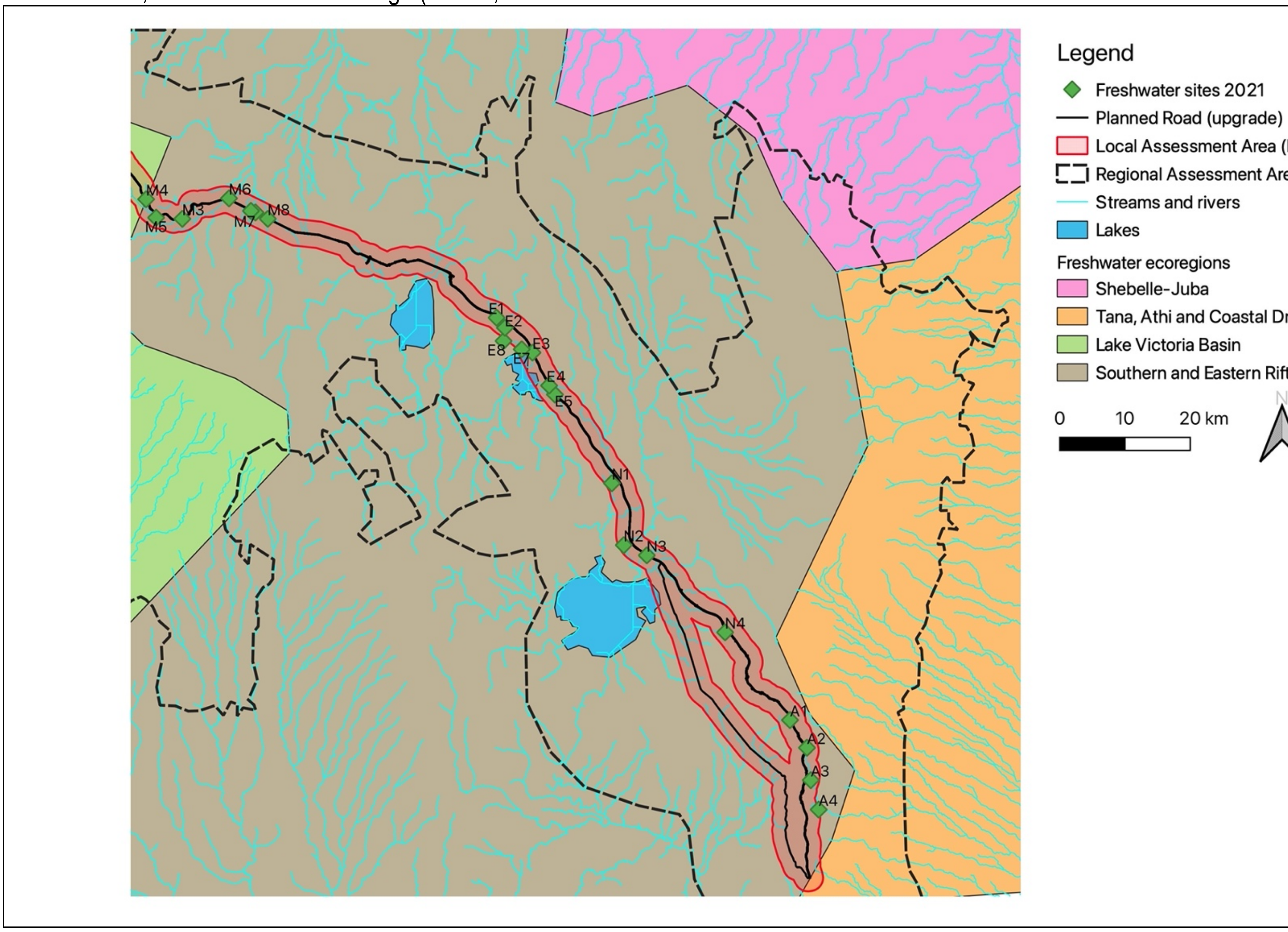
d. ≥ 1 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle and on a cyclical or otherwise regular basis; or
e. ≥10 percent of the global population of a species during periods of environmental stress.

5. Results and Discussion

5.1. Study Area Description

The general study area is directly located three Freshwater Ecoregions over a significant range in altitudinal gradients, namely:

i. Lake Victoria,
ii. Southern Eastern Rift, and
iii. Tana, Athi and Coastal Drainage (FEOW, 2021-



iv. Figure 4).

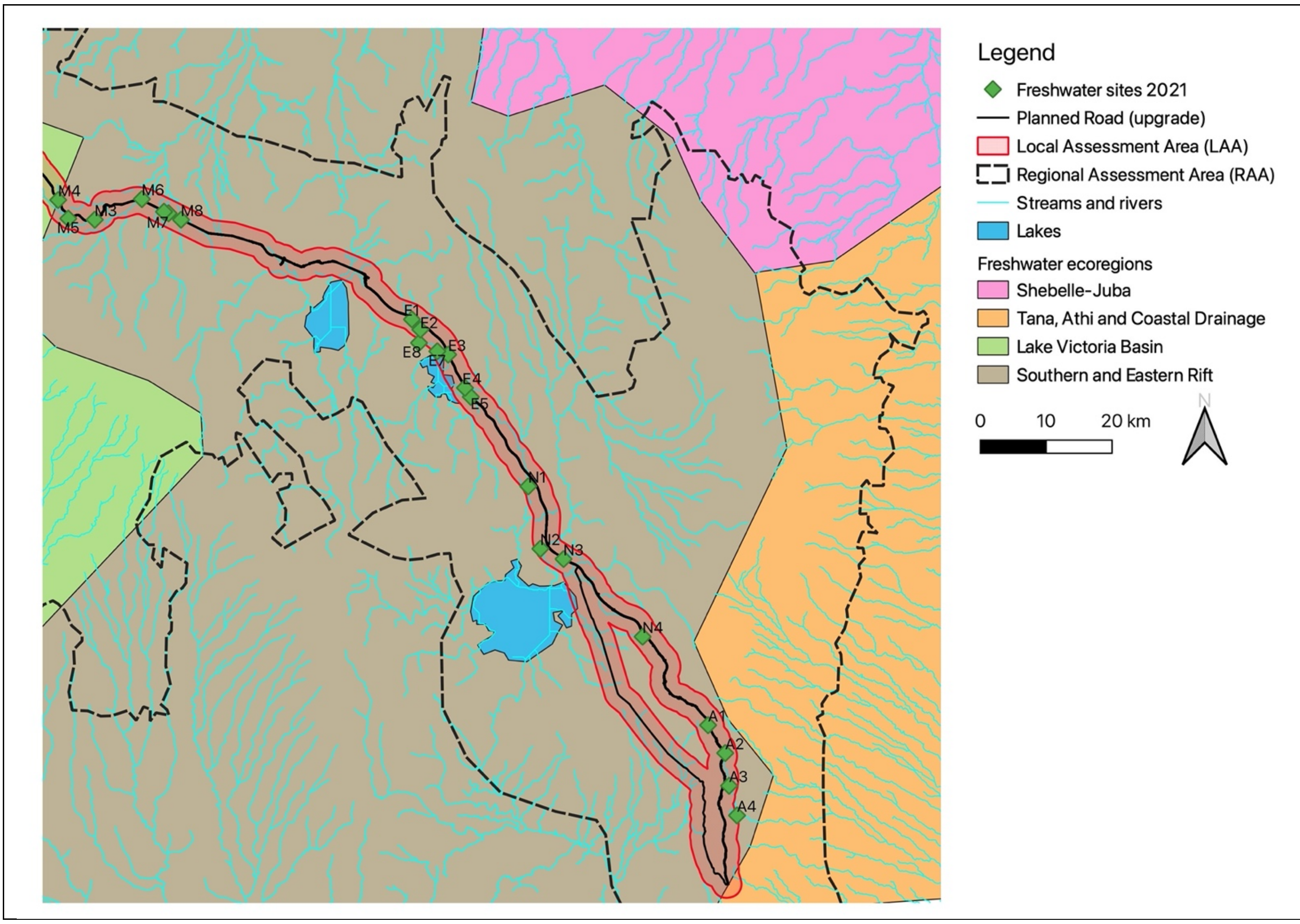


Figure 4 shows the study area and the freshwater sites that were visited in the baseline study. A small section of the most westerly footprint of the Project is situated in the Lake Victoria Catchment towards the Mau summit which includes more immediately the Yala River headwaters.

Most of the Project footprint is situated in the Southern Eastern Rift Ecoregion, which encompasses various sub-catchments which ultimately drain lakes Baringo, Nakuru, Elementeita and Naivasha. The Southern Eastern Rift Valley comprises of shallow lakes, rivers and streams, hot and cold-water springs, marshes, swamps, and salt pans which occur within the ecoregion (FEOW, 2021). The Tana, Athi and Coastal Drainage Ecoregion is situated in the most easterly area towards Rironi and drains a series of small lotic systems towards the Aberdares and Nairobi.

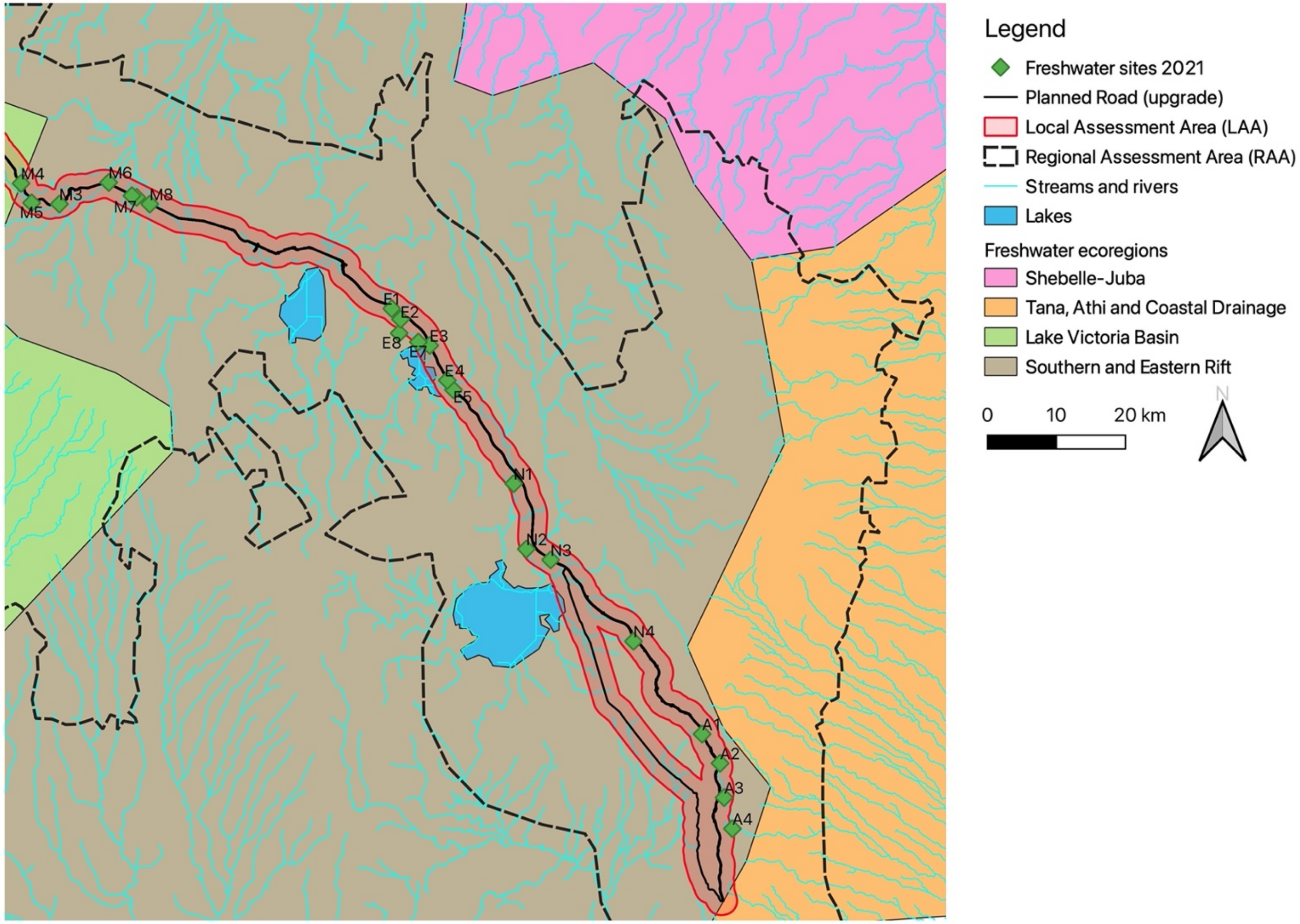


Figure 4: Map showing the study area with sites and freshwater ecoregions (FEOW, 2020).

5.2. Site Descriptions and Aquatic Habitat Types

Sites were divided into different freshwater habitat types according to various characteristics. Photographs and channel features for each site are provided in **Appendix A**. The section below describes the freshwater habitat types in more detail.

Lotic Systems[5]

5.2.1. Rivers

Rivers, for the purpose of this study, are described as main stem flowing water systems with an open canopy, a defined channel and riparian zone. Sites in this class are deep (> 2 m), wide (> 5 m) and relatively fast flowing (an example is shown in

D	E	

Figure 5A). The sites that classified as rivers are all large systems that are direct or indirect tributaries of lakes in the study area, namely the Malewa River (Naivasha catchment) and Molo River (Molo catchment).

Rivers to the west of the study area draining north to Lake Baringo catchment and south-west to the Lake Victoria catchment arise in Afromontane Forest, Afromontane Bamboo and Upper Acacia Wooded Grassland vegetation. Rivers in the central parts of the study area draining lakes Nakuru, Elementeita and Naivasha are fringed by Evergreen and semi-evergreen bushland and thicket. To the eastern part of the study area the rivers draining to the Kikuyu Escarpment and the Aberdare Range are fringed primarily by Afromontane Bamboo, Afromontane Forest, and some Edaphic vegetation elements.

5.2.2. Streams

Streams refer to small lotic, permanent freshwater systems in the study area which exhibit well-defined riparian fringe and a distinct zonation between riparian vegetation and surrounding terrestrial vegetation (

D	E	

Figure 5B). Streams are tributaries or headwaters of mainstem rivers. They are generally shallow (1 - 2 m), relatively narrow (0.5 - 5 m) and consist of a variety of substrate spanning from alluvial (sandy) to bedrock and boulder systems. Various streams systems are crossed by the proposed road upgrade along the alignment.

Perennial stream vegetation associations follow the river vegetation associations mentioned above.

5.2.3. Non-perennial streams

Non-perennial streams are associated with edaphic features in the landscape. These system flow intermittently or seasonally in response to rainfall events and are biotically less sensitive than perennial systems. Non perennial streams refer to small lotic, seasonal systems in the study area that flow intermittently, and which exhibit well-defined riparian fringe (

D	E	

Figure 5C). Non-perennial streams are tributaries or headwaters of mainstem rivers and other permanent streams. They are shallow (1 - 2 m), narrow (0.5 - 5 m) and consist of a variety of substrate spanning from alluvial (sandy) to bedrock and boulder systems. Various non-perennial stream systems are crossed by the proposed road upgrade along the alignment.

Lentic Systems [6]

[5] Flowing freshwater systems
[6] Standing freshwater water systems

5.2.4. Wetlands

Wetlands are low energy systems where the water table is near, or at, the ground surface which are natural or anthropogenic in nature (

D	E	

Figure 5D &E). Wetlands are characterised by slow flowing, shallow waters without a high cover of emergent vegetation. They are dominated by grasses, sedges and forbs and encompass areas of disperse flows. Wetlands were noted towards the south-east sections of the road alignment along the Bathi River draining towards the Aberdares.

Figure 5: Examples of broad freshwater habitat types noted in the freshwater survey (A) River (Molo River), (B) perennial stream, (C) non-perennial stream, (D) wetland and (E) artificial wetland.

5.3. Water Quality Assessment

5.3.1. *In situ* Analysis

The study area was characterised by **circumneutral to slightly alkaline waters** (Figure 6 and **Appendix B**), with sites draining to the Rift Valley having slightly more alkaline pH. The pH values ranged from 6.06 in the Lake Naivasha catchment to 8.23 in rivers draining the Rift Valley.

The Electrical Conductivity (EC) varied widely between catchments ranging between 114 and 1713 µS/cm (Figure 6). Sites draining towards the Aberdares on the Bathi River showed the **lowest ECs** (average of 246 µS/cm), where sites draining towards the lakes Elementeita, Naivasha had and the Rift Valley had high ECs indicative of land use impacts in their respective catchments (384, 397 and 563 µS/cm, respectively). Average ECs for the entire study area were higher than expected for headwater systems and are indicative of water quality degradation from associated land use.

The rivers in the overall study area were turbid and silty, especially in the Yala River, Lake Naivasha and Rift Valley catchments which showed an average turbidity's ranging between 272- 645 NTUs (Appendix B). Sites in the Molo River, Lake Elementeita and the Aberdare catchments on average ranged between 80-105 NTUs for turbidity.

5.3.1. Laboratory Analysis

The particulars on the major ions, metals and nutrients are provided in **Appendix B** showing where Target Water Quality Values (TWQRs), Chronic Effect Values (CEVs) and Acute Effect Values (AEVs) have exceeded the limits according to the guidelines for freshwater systems (DWAF, 1996). Sites on the Molo catchment showed the highest **nutrient levels** overall (Figure 7) with Nitrate levels in the Eutrophic range indicating nutrient enrichment. The remainder of the catchments had Nitrate levels that fell within the Mesotrophic range.

Most of the trace metal concentrations were low and below detection limits for most sites in the study area, however **iron, aluminium, chromium, and copper** exceeded various limits as delineated by DWAF (1996) for freshwater ecosystems in the study area. Two major ions (**fluoride and sodium**) also exceeded limits for freshwater systems at various sites (Appendix B).

The Piper Diagram can be used to fingerprint a water source based on the equivalents of the major cations and anions present at the site. All water types assessed were of the Sodium-Bicarbonate (Na-HCO_3) hydro-chemical type in both seasons (Figure 8 and Figure 9). This water type indicates dynamic and co-ordinated mixing of surface and ground water. The predominant component of the bedrock and secondary mineral composition is likely primarily Sodium based, and there is a greater cation exchange in the Na-HCO_3 types with their circumneutral to alkaline pHs and moderate alkalinities. Secondary mineralization and re-mineralization on the surfaces due to hydrothermal fluids and weathering reactions are likely with in these water types.

Figure 10A and B show the major ions in milliequivalents. The February 2021 samples show higher overall loads of salts due to decreased sustained flows in comparison to the April 2021 samples. The Aberdares catchment sites had the lowest salt loads in comparison to the other catchments, with Elementeita having the highest overall salt load likely due to a mix of the underlying geology and human influence in that catchment.

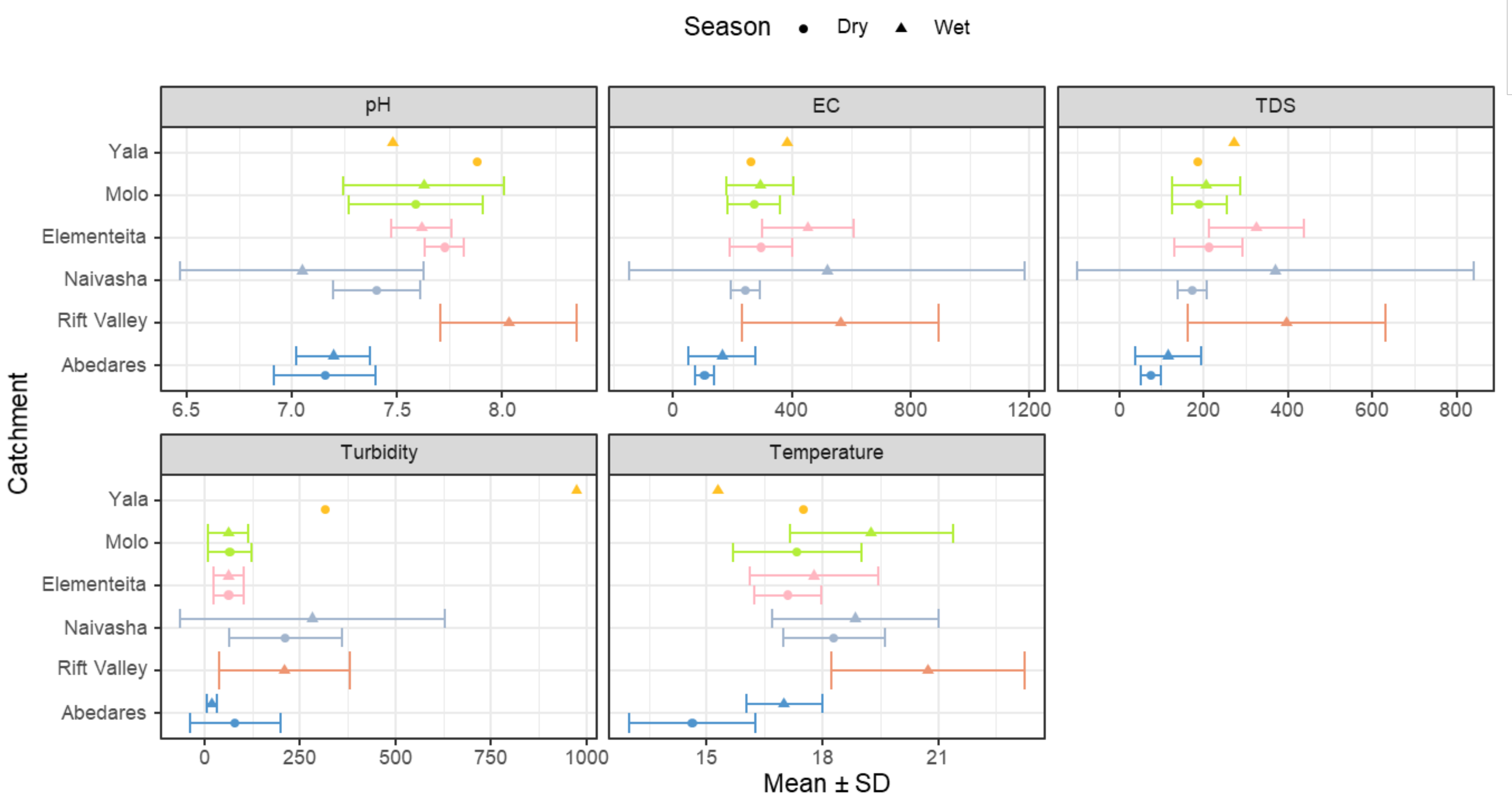


Figure 6: Bar graph showing *in situ* values and associated averages and standard deviation (SD) for the various catchment assessed in the study area

In summary, water quality samples showed that:

- Lake Elementeita and Lake Naivasha catchments were the most impacted overall in terms of water quality;
- Nutrient enrichment was most prominent in the Molo catchment, likely due to the high level of agricultural activities which encroach on the freshwater systems in the catchment;
- Turbidity was generally considered high for headwater streams, and many streams exhibited high ECs due to heavily utilised catchments;
- Elevated concentrations of Iron, Aluminium, Chromium and Copper were noted for most sites in the Lake Naivasha and Lake Elementeita catchments, with Fluoride and Sodium also exceeding limits for freshwater systems at various sites within these catchments. This is likely due to a mixture of land use impacts and geology;
- All sites were characterised as Na-HCO_3 water types, with elevated milliequivalents of major ions noted in the Elementeita and Naivasha catchments in comparison to other catchments.

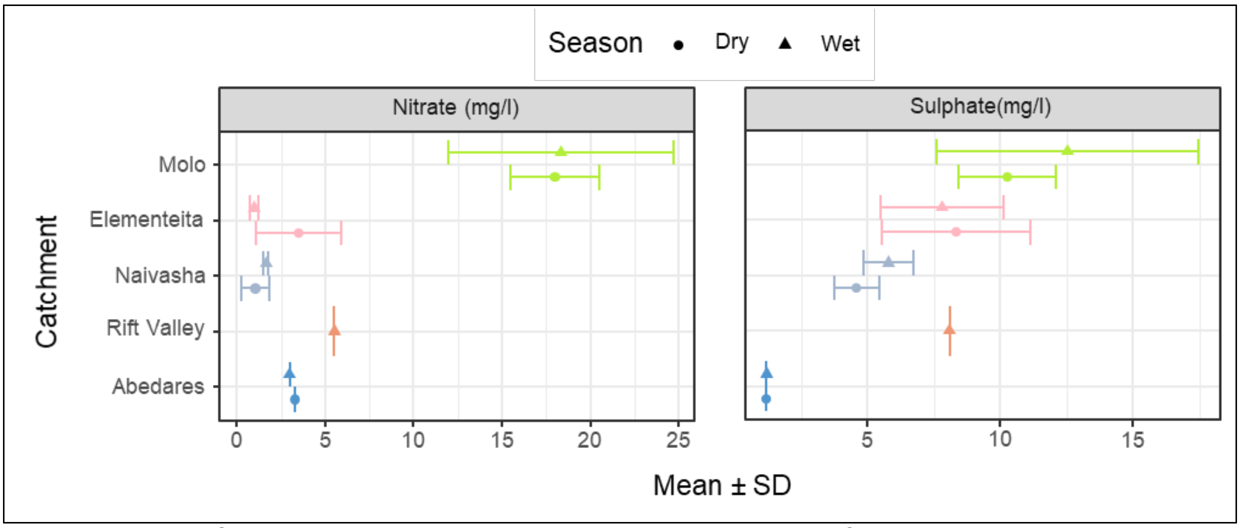


Figure 7: Nitrate and Sulphate concentrations showing average and standard deviation (SD) per catchment.

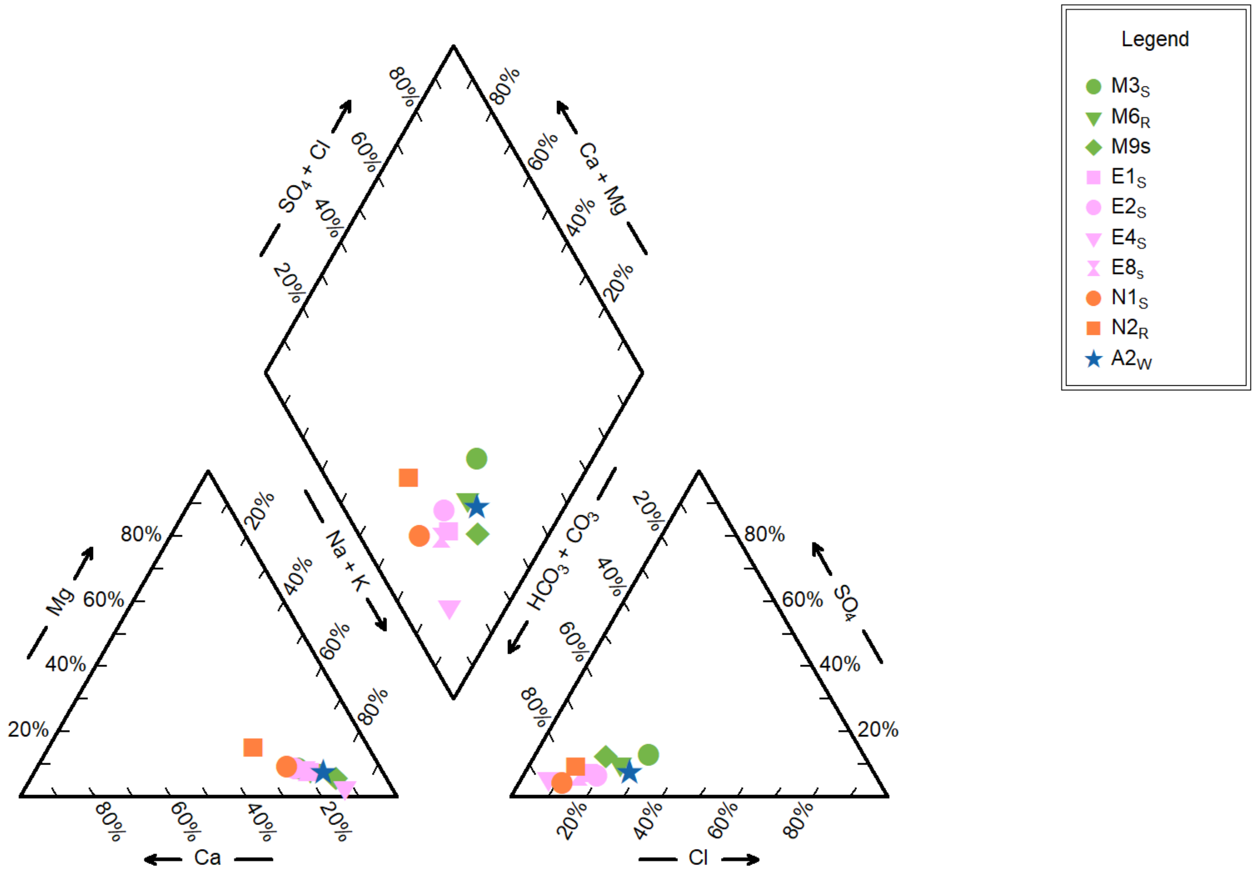


Figure 8: Piper diagrams for the February 2021 survey showing water fingerprints per site based on major ions.

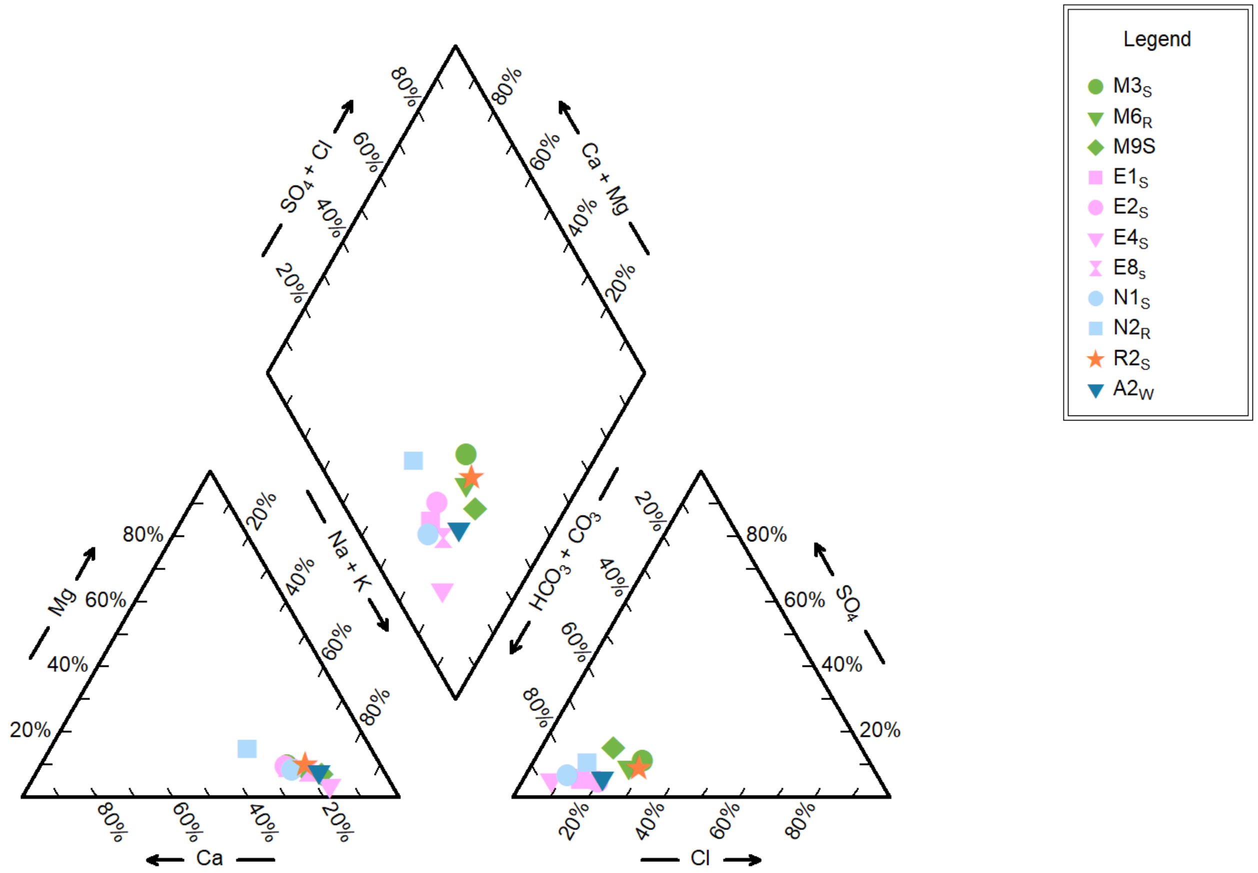
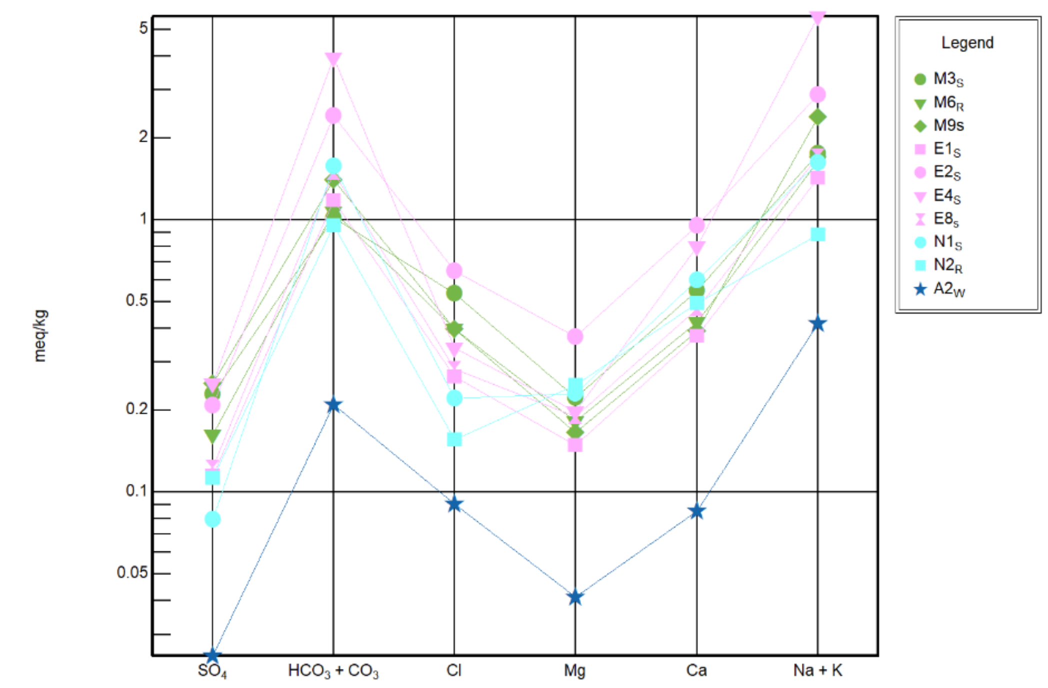


Figure 9: Piper diagrams for the April 2021 survey showing water fingerprints per site based on major ions.



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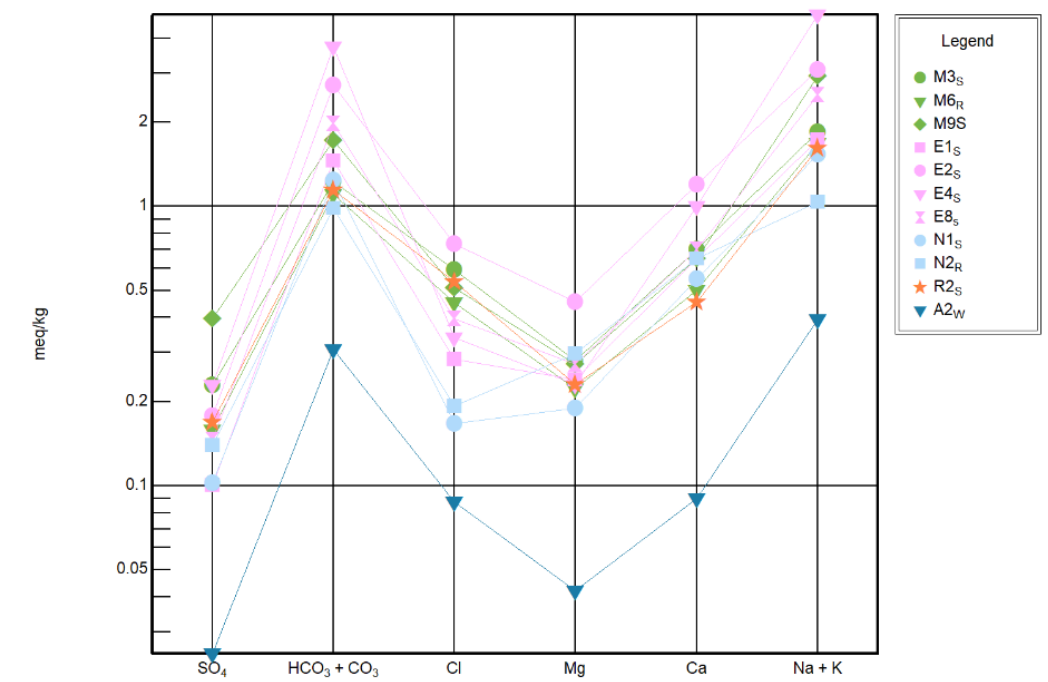

B

Figure 10: Schoeller diagrams showing the milliequivalents/kg (meq/kg) of major salts per site for (A) February 2021, and (B) April 2021

5.4. Habitat Assessment

5.4.1. Habitat Integrity

The IHI assessment (Kleynhans, 1996) was applied to ascertain the change of instream and riparian habitat from natural conditions on a site and catchment basis. The results of the IHI were used to designate Natural and Modified Habitat as per IFC PS6 (IFC, 2012). The IHI assessment provides a tool for assessing habitat by incorporating various factors and potential impacts (Kleynhans, 1996). This section discusses the overall integrity of the study area, highlighting sites of concern and sites with a higher sensitivity.

The habitat integrity assessment showed that the **48.7 %** of the sites assessed were in a ***Largely Modified* state**, where a considerable loss of natural habitat, biota and basic ecosystem functions has occurred (Figure 11). These sites are classified as **Modified Habitat as per IFC PS6** (IFC, 2012). The remainder of the sites (**51.3%**) were **Moderately Modified to Largely Natural** where ecosystem function was less impacted, and the sites have the potential to support a relatively natural community (Figure 11). These sites in IHI class as **Natural Habitat based on the IFC PS6 criteria**.

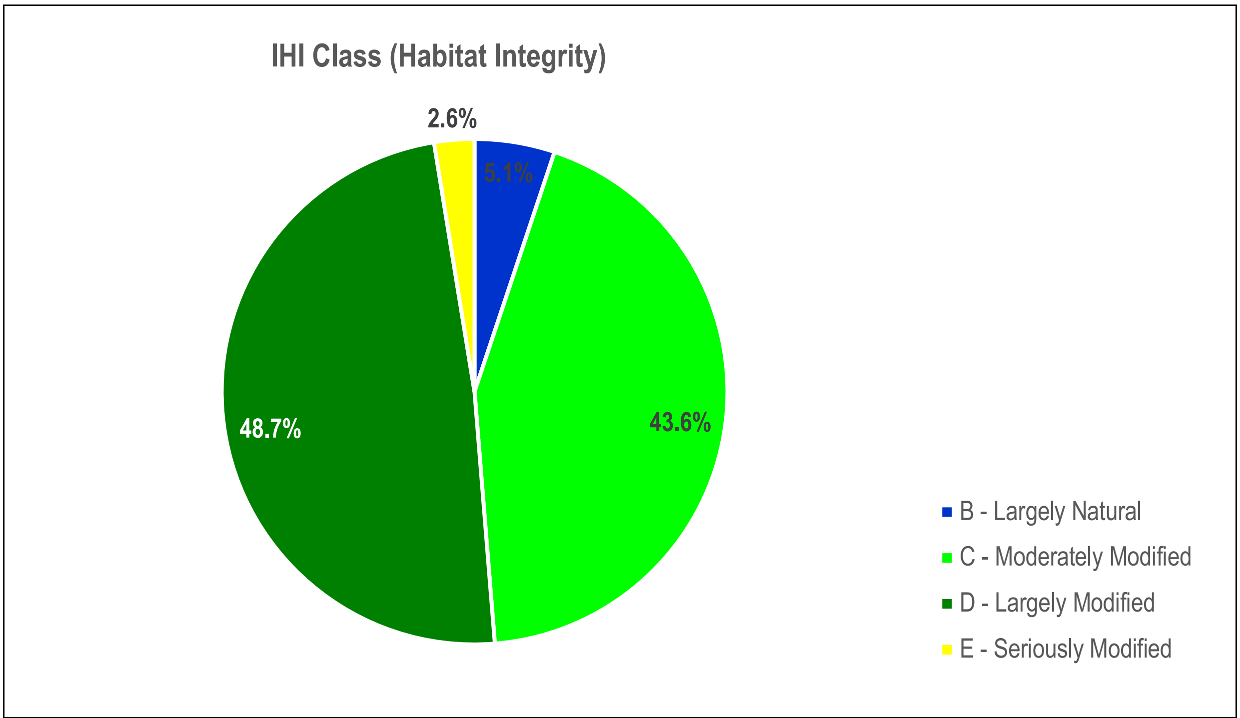

Figure 11: Pie chart illustrating the percentage distribution of the associated IHI categories for the freshwater study sites.

The study area obtained an average IHI percentage of 60.4 %, indicating an overall *Largely to Moderately Modified* state along the road alignment, with the riparian habitat integrity scoring considerably lower (56%) compared to that of the instream habitat (64.9% Figure 13). A principal components analysis (PCA) was completed on the full habitat integrity data matrix to determine clustering and variable importance where a higher value represents higher importance (Figure 12). Lake Elementeita sites had the highest habitat integrity whereas Lake Naivasha sites had the poorest habitat integrity. The five variables with highest importance for driving habitat deterioration are:

- Vegetation removal,
- Flow modification,
- Water abstraction,
- Exotic vegetation and fauna, and
- Channel modification.

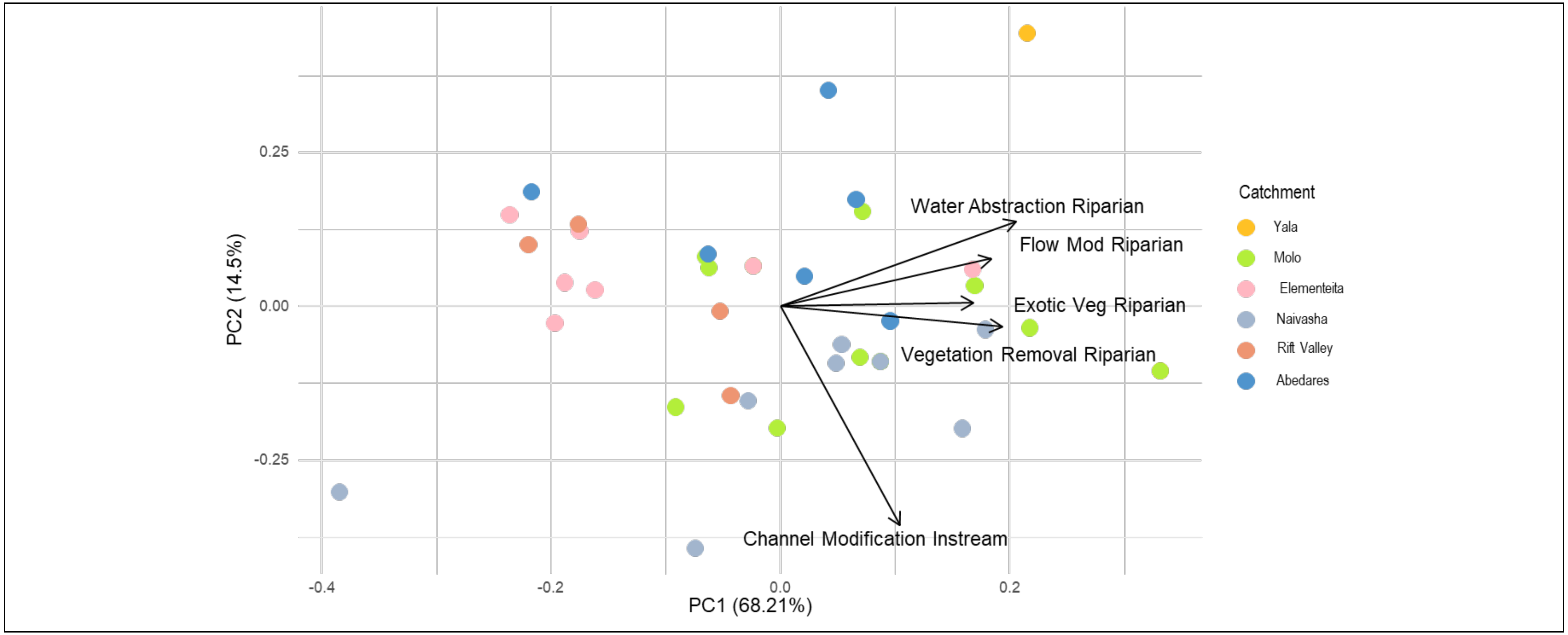

Figure 12: PCA of habitat integrity drivers showing the 5 most important drivers of habitat integrity in the various catchments.

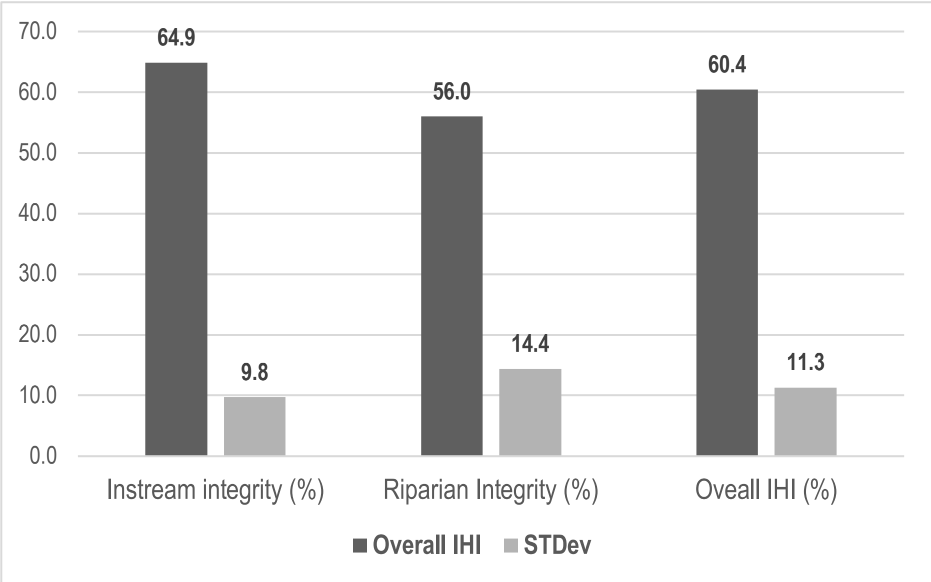

Figure 13: Column graphs indicating the average overall instream and riparian Habitat Integrity and the Average (Avg) IHI % for sites in the study area.

The Lake **Elementeita, Rift Valley and Aberdare** catchments obtained the highest overall integrity classing in C categories and as **Natural Habitat** as per IFC PS6 (Figure 14 & Table 15). The **Yala, Molo and Naivasha** catchments classified in a D category and as **Modified Habitat** (IFC, PS6). Details of the baseline condition for each site are noted in **Appendix C**.

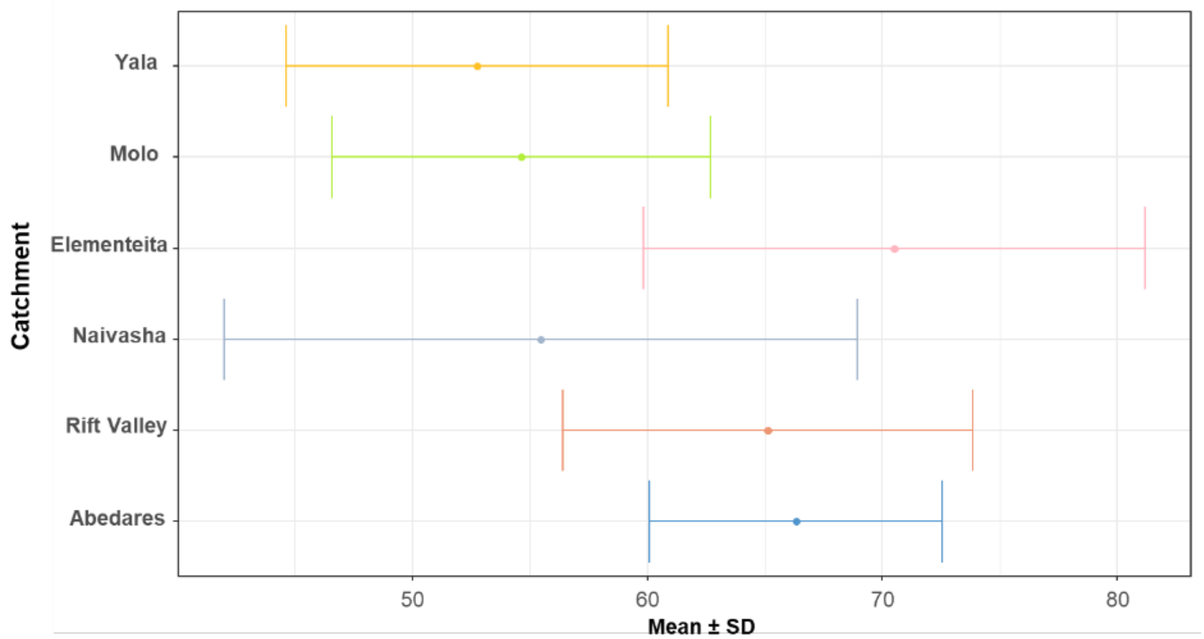

Figure 14: Average IHI represented per catchment with Standard Deviation (SD)

Table 15: Average overall Habitat Integrity for the different catchments and associated IFC PS6 habitat classification

Catchment	Instream Integrity (%)	Riparian Integrity (%)	Overall IHI (%)	IHI Category	Habitat Classification (IFC PS6)
Yala River	63.5	42.0	52.8	D	Modified Habitat
Molo River	59.4	49.8	54.6	D	Modified Habitat
Lake Nakuru	60.2	60.2	60.2	C/D	Natural/Modified
Lake Elementeita	73.6	64.6	69.1	C	Natural Habitat
Lake Naivasha	58.0	53.0	55.5	D	Modified Habitat
Rift Valley	67.5	62.8	65.1	C	Natural Habitat
Aberdares	72.1	60.6	66.3	C	Natural Habitat

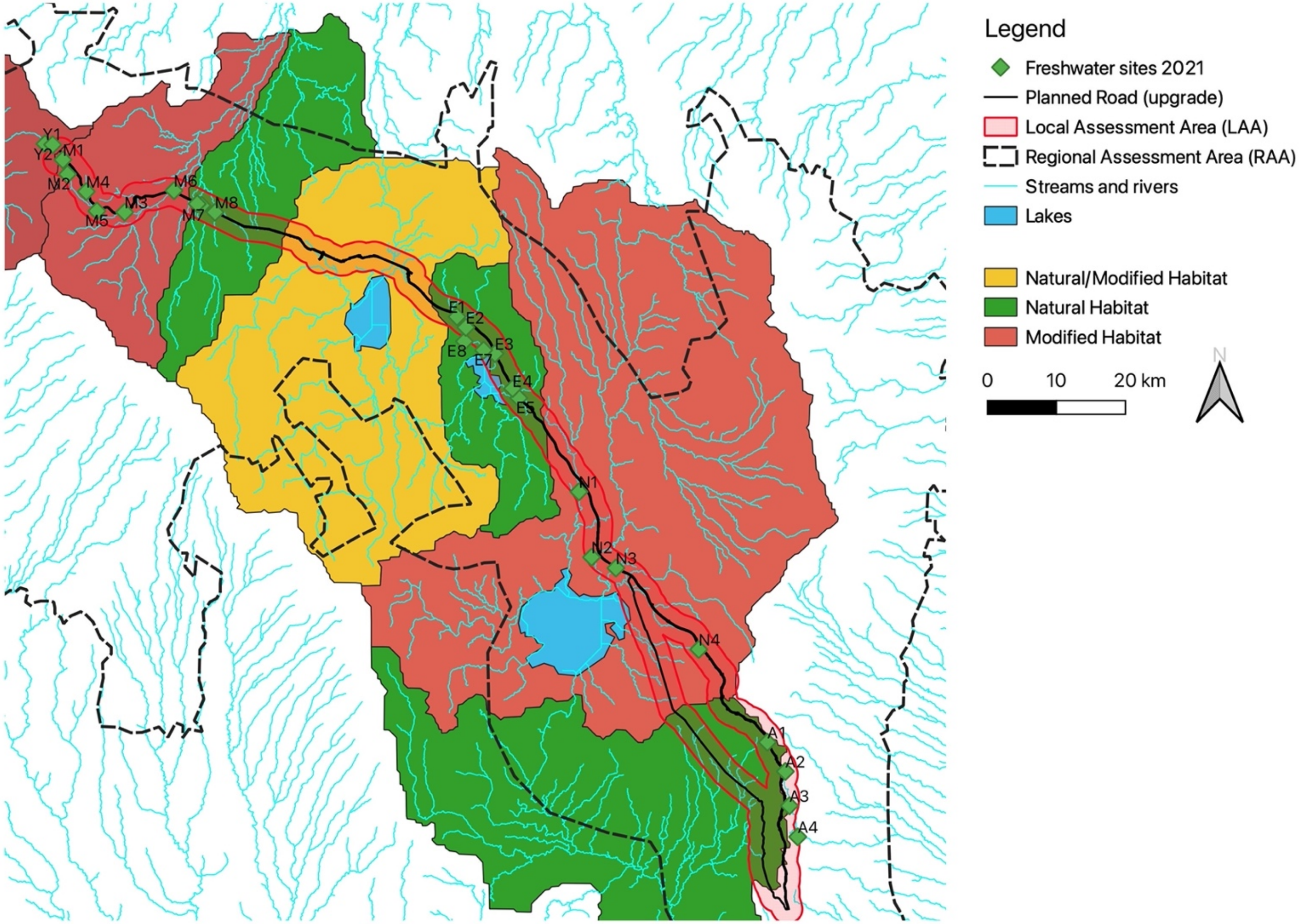

Figure 15: Map indicating the sites with natural and modified habitat as per IFC PS6.

5.4.2. Macroinvertebrate Habitat Availability

Habitat availability (quality and quantity) is an important part of an ecosystem as it forms a template for the biotic communities. Habitat availability and diversity are major determinants in the overall community structure of aquatic macroinvertebrates. For this reason, it is important to evaluate habitat quality and quantity when applying biomonitoring methodologies and assessing ecosystem health.

Concerning macroinvertebrate habitat in the different catchments, the Aberdare and Elementeita catchments obtained the lowest average IHAS % scores (Figure 16). Concurrently, the Molo and Naivasha catchments obtained the highest habitat availability with all these sites pre-dominantly consisting of Stones in Current (SIC) and Gravel Sand and Mud (GSM - other habitat) with available overhanging vegetation. Details per site can be seen in **Appendix D**.

The different biotopes included in this assessment were Stones in Current (SIC) Vegetation (Veg) and Other/General (McMillan, 1998). Other/General less dominant habitats comprised of Stones Out of Current (SOOC), Gravel, Sand and Mud (GSM) and bedrock. The biotopes dominating most of the sites included GSM (Figure 17). Sites assessed reflected ***Poor*** **to** ***Adequate*** **habitat diversity for aquatic macroinvertebrates** (**Error! Reference source not found.**).

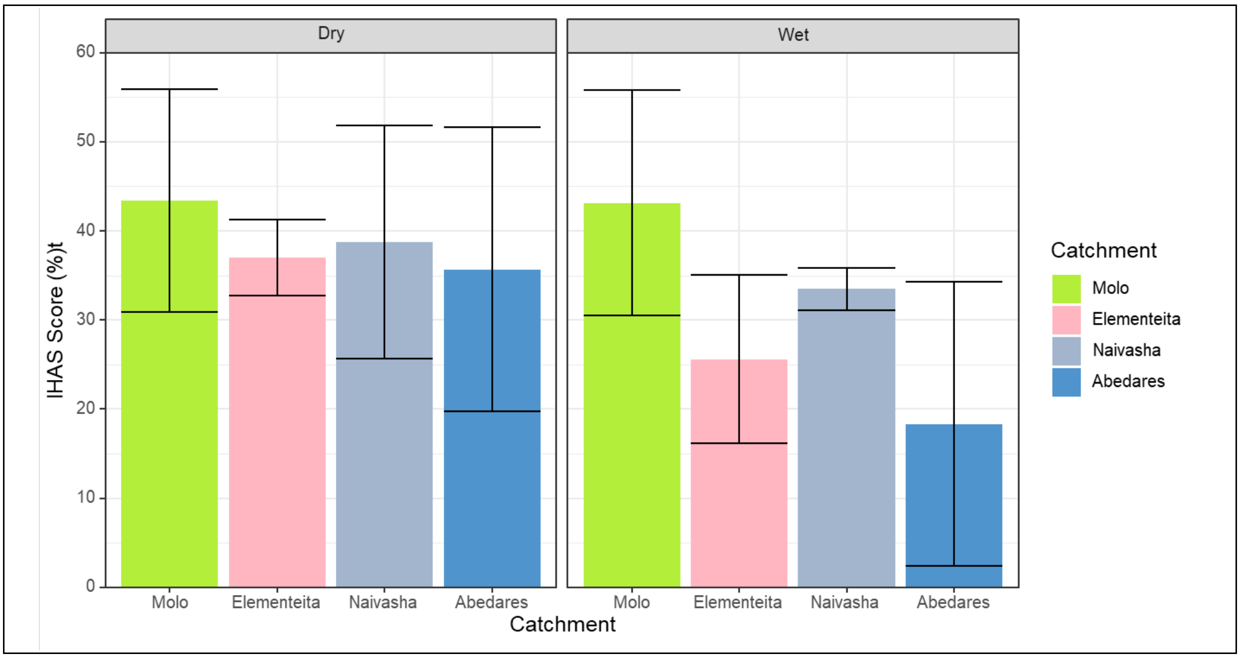

Figure 16: Average total IHAS % for the different catchments associated with the study area during the dry and wet seasons.

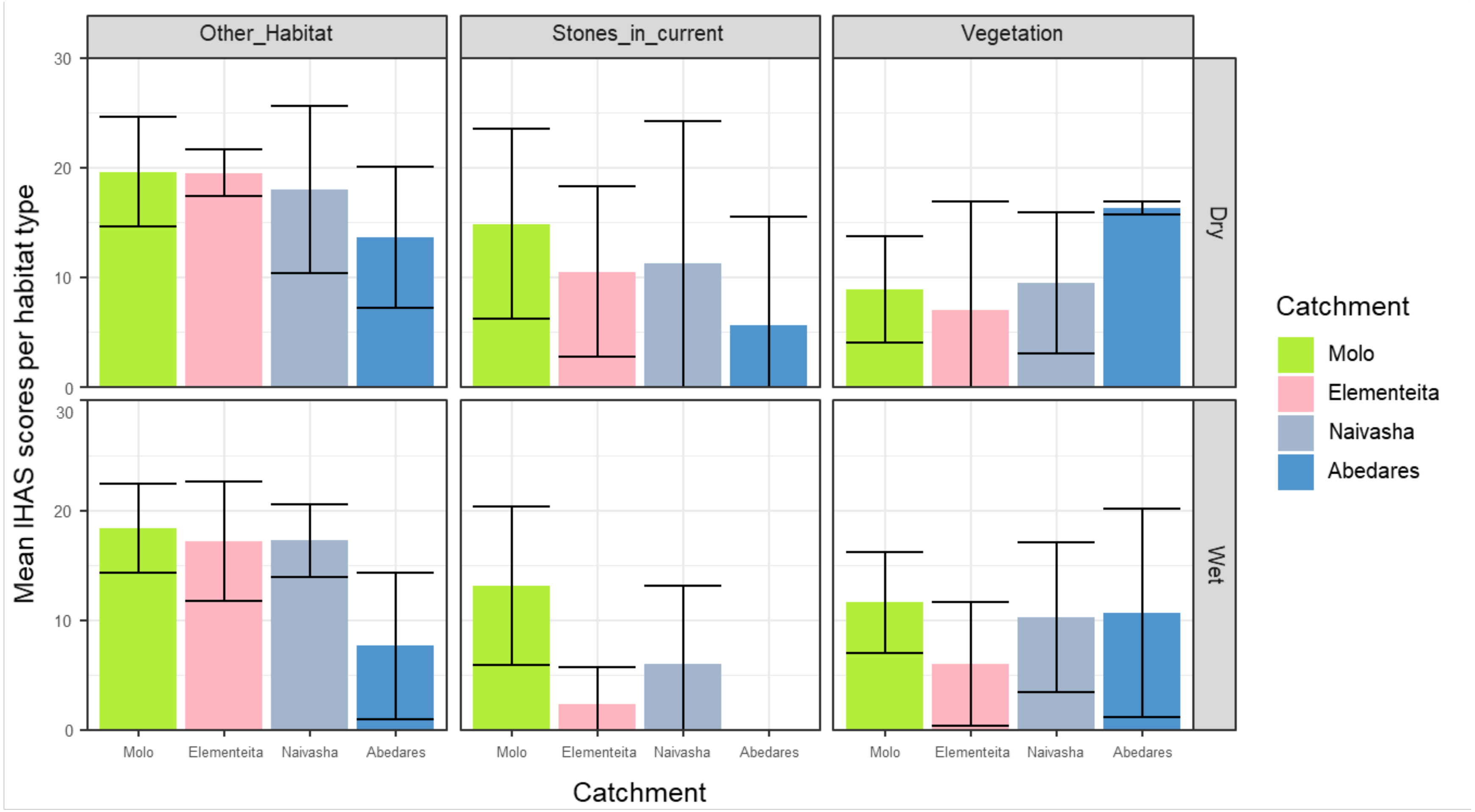

Figure 17: Average habitat score per macroinvertebrate habitat component per catchment showing Standard Deviation.

5.4.3. Fish Habitat

The fish habitat assessment allows for the comparison and interpretation of fish data between sites, highlighting dominant cover and velocity-depth classes associated with each habitat type which drive the fish community (**Appendix E**). The dominant velocity classes associated with the study area were slow-deep (SD), slow-shallow (SS) and slow-very-shallow (SVS) at most of the sites assessed (Figure 18). This would support a more general community with less rheophilic fishes and species that are used to slow lotic conditions.

The study area consisted of a diverse range of habitat types and cover with sand and bedrock dominating substrate types, and root wads and emergent vegetation showing the highest percentage of habitat cover at the majority of the sites assessed (Figure 19 & Figure 20). Most freshwater systems had a good mix of habitat and should in theory be able to support a natural community of fishes.

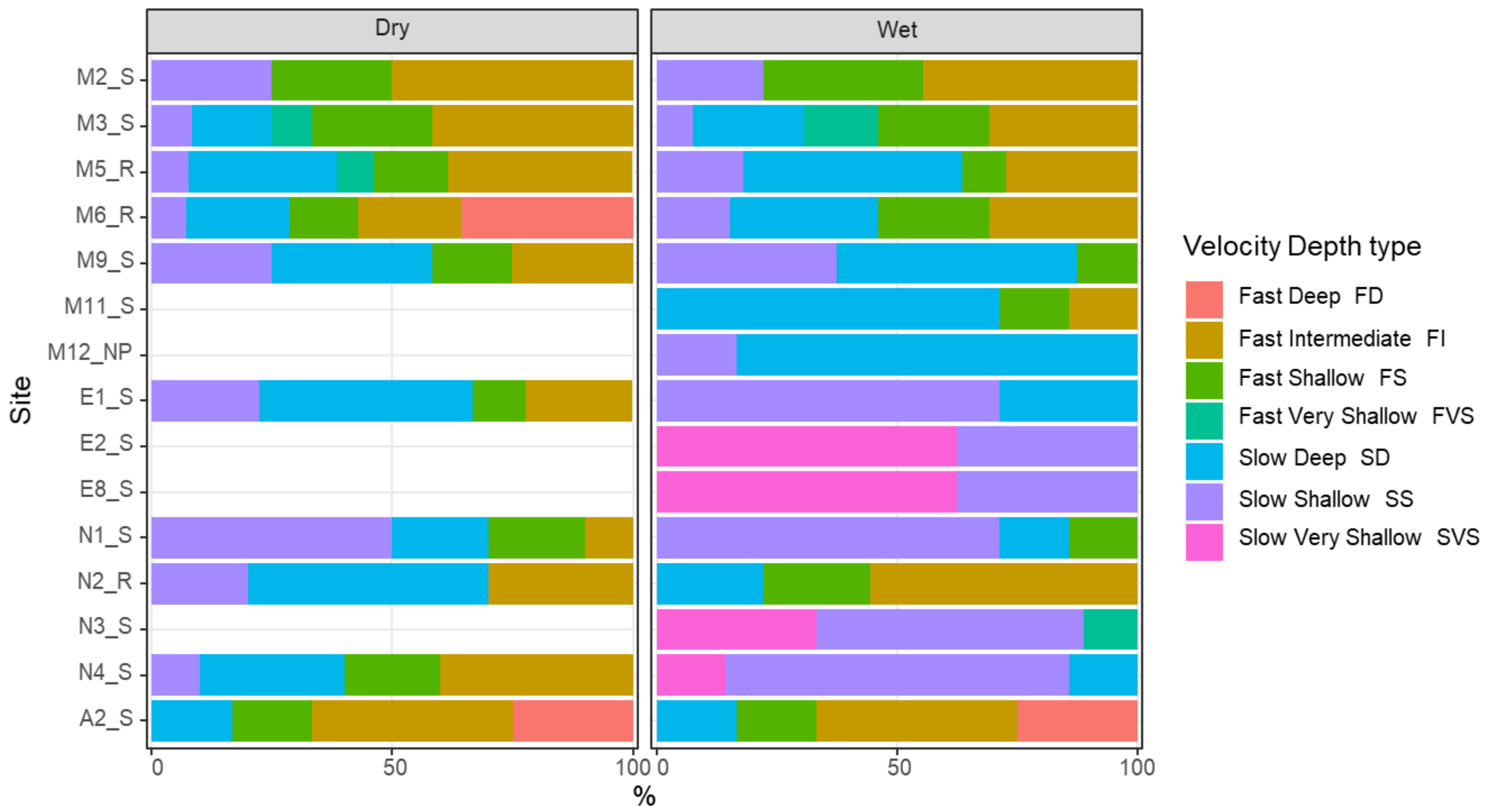

Figure 18: Fish habitat showing velocity-depth types per fish sampling site.

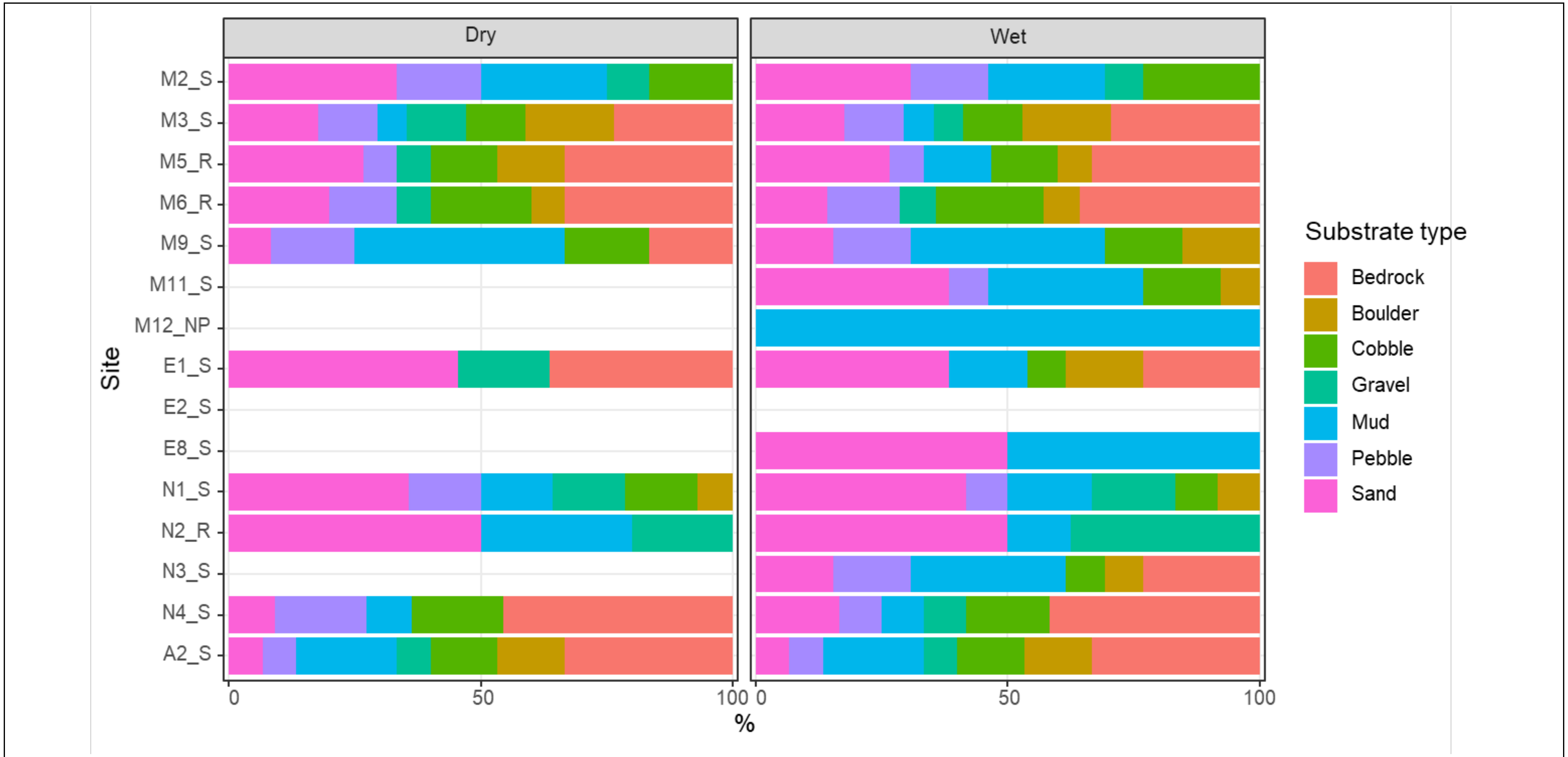

Figure 19: Fish habitat showing substrate types per fish sampling site.

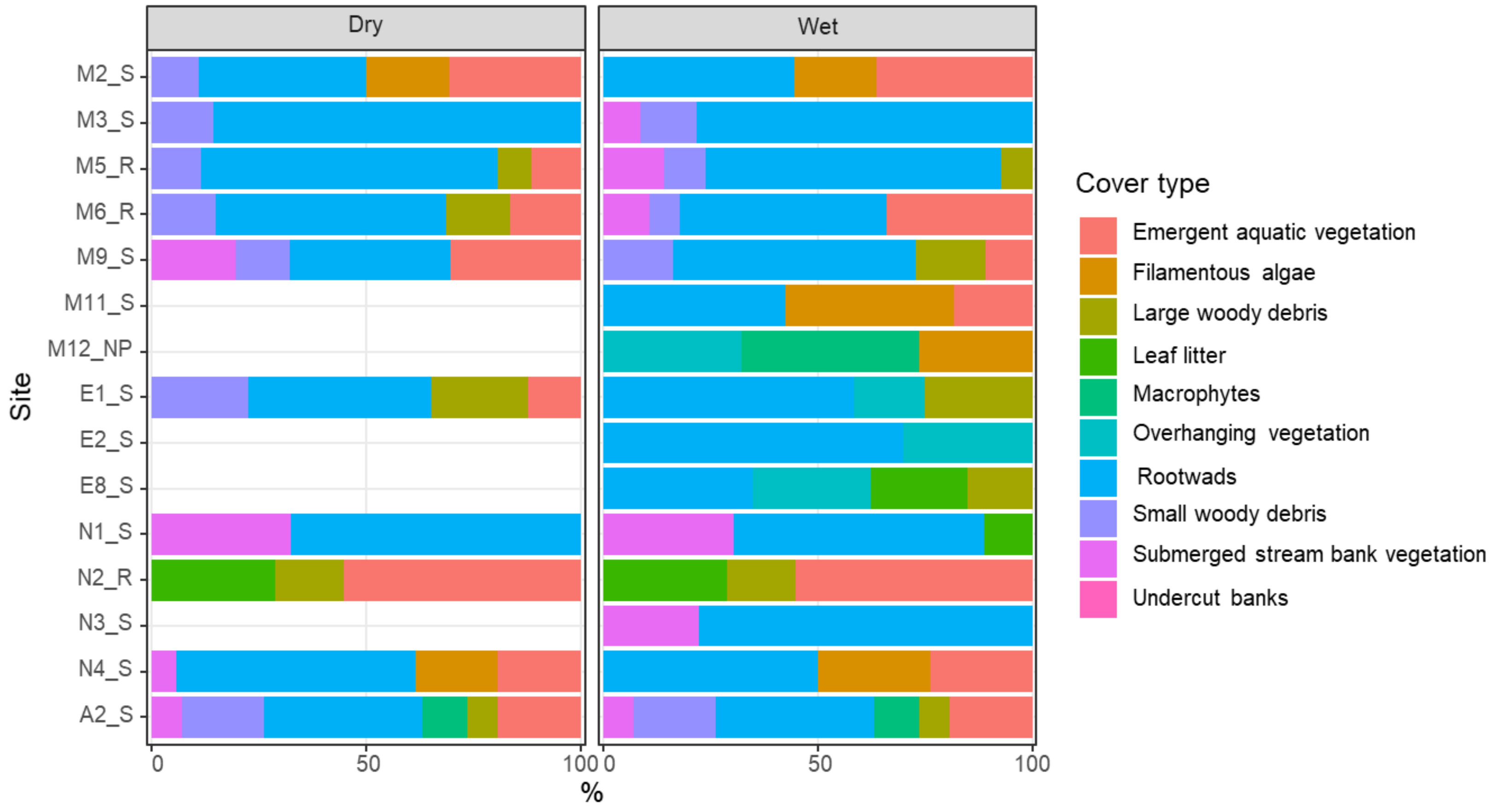

Figure 20: Fish habitat showing cover types per fish sampling site.

5.5. Diatom Assessment

5.5.1. Diatom Community Structure

The diatom assessment is divided into three sub-sections: (i) Discusses the ecological classification of water quality for each site according to the diatom assemblage during this assessment. (ii) Provides analysis and discussion of the dominant species and their ecological preferences at each site. Thus, allowing spatial variation analyses of ecological water quality between sites. (iii) Discusses the temporal trends of the diatom community (February 2021 to April 2021).

5.5.2. Ecological classification for water quality

The ecological classification for water quality according to Van Dam et al. (1994) and Taylor et al. (2007), includes the preferences of diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state as provided by OMNIDIA (Le Cointe et al., 1993) (Table 16). The overall diatom assemblages comprised of species with a preference for:

- Fresh brackish (<500 µS/cm), circumneutral (pH 6.5 - 7.5) to alkaline (pH > 7.5) waters with moderate to very high levels of nutrients;
- The nitrogen requirements for all the sites ranged from N-Autotrophic tolerant, indicating a tolerance for elevated concentrations of organically bound nitrogen to N-Heterotrophic facultative, indicating a requirement for periodically elevated concentrations of organically bound nitrogen;
- The dissolved oxygen saturation ranged from moderate (50%) to very high (~100%) for all the sites;
- The pollution levels indicated that there was low to moderate levels of pollution reflecting unpolluted to strongly polluted conditions present at all the sites.

Table 16: Ecological descriptors for the sites based on the diatom community (Van Dam et al., 1994 and Taylor et al., 2007)

Site	pH	Salinity	Organic Nitrogen uptake	Oxygen Levels	Pollution Levels	Trophic State
M3_S	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Moderately polluted	Eutrophic
M6_R	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Moderately polluted	Eutrophic
M9_S	Circumneutral	Fresh brackish	N-Autotrophic tolerant	Very high	Moderately polluted	Eutrophic
M11_S	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Moderately polluted	Eutrophic
N1_S	Circumneutral	Fresh brackish	N-Autotrophic tolerant	Moderate	Moderately polluted	Eutrophic
N2_R	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Moderately polluted	Eutrophic
E1_S	Circumneutral	Fresh brackish	N-Heterotrophic facultative	Moderate	Moderately polluted	Eutrophic
E4_s	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Strongly polluted	Eutrophic
E8_NP	Circumneutral	Fresh brackish	N-Heterotrophic facultative	Moderate	Strongly polluted	Eutrophic
R2_S	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Moderately polluted	Eutrophic
A1_S	Alkaline	Fresh brackish	N-Autotrophic sensitive	High	Unpolluted to slightly polluted	Indifferent
A2_S	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Unpolluted to slightly polluted	Indifferent
A5_W	Alkaline	Fresh brackish	N-Autotrophic tolerant	Moderate	Strongly polluted	Indifferent

5.5.3. Diatom spatial analysis

A total of 63 diatom species were recorded at the 13 sites and the dominant species recorded included *Nitzschia* sp., *Navicula* sp. and *Gomphonema* sp. (**Appendix F**). These taxa are cosmopolitan in nature and have wide ecological amplitudes. It is important to consider these dominant species in conjunction with the entire diatom assemblage when analysing the results. Diatom communities reflect ecological conditions over a period of 2-3 weeks. Therefore, diatom communities require enough time for establishment to reflect these conditions. During this survey site M10_W had insufficient cell counts and was thus excluded from analyses. Ecological information is provided below for the dominant and sub-dominant species to make ecological inferences for the 13 sites (Table 17; Appendix E, Taylor et al., 2007):

Molo River catchment

- The ecological water quality at sites M3_S and M6_R on the Molo River System reflected ***Poor* and *Moderate* conditions** with low levels of organic pollution, respectively (Table 17). Site M3_S was dominated by taxa that pointed to eutrophic running water with medium to high conductivity. This site appears to be disturbed and owing to the low levels of organic pollution, the disturbance may be attributed to an excess in nutrients. Site M6_R was dominated by taxa that pointed to meso-to eutrophic conditions with medium to high electrolyte content. This site appears to be disturbed by an excess of nutrients. Sites M9_S and M11_S reflected *Poor* conditions with moderate levels of organic pollution (Table 17). Both sites were dominated by taxa that pointed to eutrophic and polysaprobic freshwater habitats with high electrolyte content and tolerant to organic pollution. These two sites appeared to be disturbed by organic pollution.

Lake Elementeita catchment

- The ecological water quality at sites E1_S, E4_S and E8_S all reflected ***Poor* conditions** with low to moderate levels of organic pollution (Table 17). Site E1_S on the Mereronai River System was dominated by taxa that reflected eutrophic, mesosaprobic conditions with moderate electrolyte conditions. Site E4_S was dominated by taxa that pointed to eutrophic conditions with medium to high electrolyte content and pollution tolerant. Site E8_S was dominated by taxa that pointed to oligo-to mesotrophic conditions with high electrolyte content, bordering on brackish conditions. All three sites appeared to be disturbed by moderate levels of organic pollution, except for site E8_NP which showed low levels of organic pollution suggesting that an excess of nutrients (i.e., nitrogen and phosphorous- naturally occurring) may be present at this site.

Lake Naivasha catchment

- The ecological water quality at site N1_S on the Morendat River system reflected ***Poor* conditions** with moderate levels of organic pollution (Table 17). This site was dominated by taxa that pointed to eutrophic and polysaprobic freshwater habitats with high electrolyte content and associated with polluted conditions. The subdominant taxa pointed to oligo to mesotrophic freshwater habitats with medium electrolyte content. This site appeared to be disturbed by organic pollution (i.e., high levels of organic matter, for example from runoff of manure or sewage). Whereas the ecological water quality at site N2_R on the Malewa River reflected *Moderate* conditions with low levels of organic pollution (Table 17). This site was dominated by taxa that reflected meso-to eutrophic running water with medium to high conductivity. This site appeared to be relatively undisturbed by organic pollution.

Rift Valley catchment

- The ecological water quality at site R2_S reflected ***Moderate* conditions** with low levels of organic pollution (Table 17). This site was dominated by taxa that pointed to meso-to eutrophic running water with medium to high conductivity and tolerant to slightly polluted conditions.

Aberdares catchment

- The ecological water quality for the sites on the Bathi River system reflected ***Good*** **to** ***Moderate*** **conditions** with low levels of organic pollution (Table 17). All three sites were dominated by taxa that pointed to oligo-to mesosaprobic conditions with medium to high electrolyte content. Site A2_S reflected *Good* conditions with no evidence of organic pollution present, suggesting that this site is undisturbed. Whereas sites A1_S and A5_W reflected *Moderate* conditions with low levels of organic pollution, suggesting that there may be slightly higher levels of nutrients (i.e., nitrogen and phosphorus) present at these sites.

Table 17: Diatom index scores for the study sites indicating the ecological water quality.

Site	%PTV	SPI	Ecological Category (EC)	Class
M3_S	7.1	9.6	**D**	Poor
M6_R	4	10.6	**C/D**	Moderate
M9_S	26.5	8.9	**D**	Poor
M11_S	24.4	7.9	**D/E**	Poor
E1_S	22.9	9.5	**D**	Poor
E4_S	23.1	8.3	**D**	Poor
E8_S	16.3	7.7	**D/E**	Poor
N1_S	23.4	8.3	**D**	Poor
N2_R	2.3	13.7	**C**	Moderate
R2_S	13.9	12.4	**C**	Moderate
A1_S	6.1	13.8	**C**	Moderate
A2_S	0	15.5	**B**	Good
A5_W	6.2	12.3	**C**	Moderate

5.5.4. Diatom temporal analysis

It is important to monitor temporal trends in the diatom community to determine any variation in the ecological conditions of the aquatic environment and the associated impacts if any. A few sites were only measured once and thus no temporal analyses was possible. Temporal analyses were surmised for all the sites over the entire monitoring period (February 2021 to April 2021) (Table 18). The main points are briefly discussed below:

- The ecological water quality at site A2_S, E4_S and N1_S remained in a stable state since the previous survey reflecting *Moderate* to *Poor* conditions. The level of organic pollution also appeared to remain in a stable state since the previous survey, reflecting low to moderate levels of pollution. Site M9_s reflected stable conditions despite the increase in the level of organic pollution;
- The ecological water quality at sites E1_S, N2_S and M6_R appeared to show a decline reflecting *Moderate* and *Poor* conditions from the February 2021. The level of organic pollution for site E1_S increased, however, for sites N2_R and M6_R the level of organic pollution remained in a stable low condition compared to the previous survey;
- Over the entire monitoring period, sites A2_S and N2_R reflected the best ecological conditions with the low levels of organic pollution compared to the other sites. Sites E4_S and N1_S on average reflected the poorest conditions with high levels of organic pollution compared to the other sites.

Table 18: Temporal trend analysis of the diatom results (February 2020- April 2021)

Site	SPI		Trend	%PTV		Trend
	Feb-21	Apr-21		Feb-21	Apr-21	
M6_R	13	10.6	▼	0.9	4	▶
M9_S	8.3	8.9	▶	11.9	26.5	▼
E1_S	10.2	9.5	▼	9.7	22.9	▼
E4_S	9.7	8.3	▶	27.2	23.1	▶
N1_S	8.3	8.3	▶	22	23.4	▶
N2_R	14.3	13.7	▼	0	2.3	▶
A2_S	15.1	15.5	▶	1.4	0	▶

In summary the diatom assessment showed the following:

- The diatom assemblages were generally comprised of species characteristic of fresh brackish, circumneutral to alkaline waters with low to high levels of nutrients. The pollution levels indicated that to strongly polluted conditions at all the sites;
- The ecological water quality showed spatial variation between the sites on the different systems. All the sites reflected ***Moderate*** **to** ***Poor*** conditions with low (<20%) to moderate (20-40%) levels of organic pollution, Except for site **A2_S (Bathi River) which reflected** ***Good*** **conditions** with no evidence of organic pollution present;
- The disturbances at the sites reflecting *Poor* conditions may be associated with runoff from the surrounding landscape or from anthropogenic inputs into the system; however, it is difficult to distinguish between the impacts;
- Since the previous survey, the ecological water quality at site A2_S, E4_S, M9_S and N1_S remained in a stable state reflecting *Moderate* to *Poor* conditions;
- The ecological water quality at sites E1_S, N2_R and M6_R appeared to show a decline reflecting *Moderate* and *Poor* conditions since the previous survey;
- Over the entire monitoring period, sites A2_S and N2_R on average reflected the best ecological conditions with the low levels of organic pollution compared to the other sites, whereas site E4_S and N1_S reflected the poorest conditions with high levels of organic pollution compared to the other sites.

5.6. Macroinvertebrate Assessment

5.6.1. Macroinvertebrate Diversity

The results of the macroinvertebrate diversity indices are presented in Figure 21-Figure 23 and detailed baseline results are contained within **Appendix G**. Shannon-Wiener and Pielou's indices were used as the main indicators of diversity. Results of Shannon's index showed that diversity and evenness were on average similar between catchments, with the **Naivasha catchment and the Elementeita catchment showing marginally lower diversity scores than the Molo and Aberdare catchments**. Diversity values were similar to studies undertaken in the Moiben River Basin in Kenya which has similar land uses and levels and a high population density (Masese *et al*., 2009)

5.6.1. Macroinvertebrate Sensitivity

Three macroinvertebrate stress response methods were applied in this study, namely No. Taxa (Families) ASPT and %EPT, all of which are a measure of macroinvertebrate sensitivity. The higher the ASPT and %EPT scores the more sensitive the site is with regards to the taxa present.

The number of taxa sampled over all sites in the study area ranged from 10 to 27 taxa, with the **highest average number of taxa sampled in the Molo catchment** (18-18.3 families) and the **lowest in the Elementeita catchment** (11-14.7 families - Figure 24). These numbers are low in comparison to other studies in similarly impacted areas in Kenya which recorded 31-41 taxa for impacted sites (Masese *et al*., 2009)

The ASPT results (Figure 24) indicate all catchments were similar in terms of average ASPT scores over all seasons, ranging from 3.9-5.5, thus showing **similar sensitivities over the study area** in terms of macroinvertebrates. The exception was the Elementeita catchment in April 2021, which showed a sharp decline in the ASPT value (3.9).

Average %EPT scores were comparable between catchments but showed overall lower score in the present study when compared to the Masese et al (2009) (Figure 25). The Molo catchment had the highest sensitivities based on aquatic macroinvertebrates, where the other catchments assessed in the study area had an overall lower sensitivity.

The overall study area showed poor to adequate habitat availability for macroinvertebrate colonization. Since macroinvertebrate communities are strongly affected by habitat variables, the lack of habitat availability is an important limiting factor affecting the diversity of the assemblage (Holmes *et al*., 2011). From data collected in the study, it was noted that the habitat type assessed were drivers of diversity, however land use impacts which affect water quality are the biggest drivers of the lower sensitivities in the general study area as is noted in the water quality impacts in Appendix B which showed that the Molo River had less impact than the other catchments.

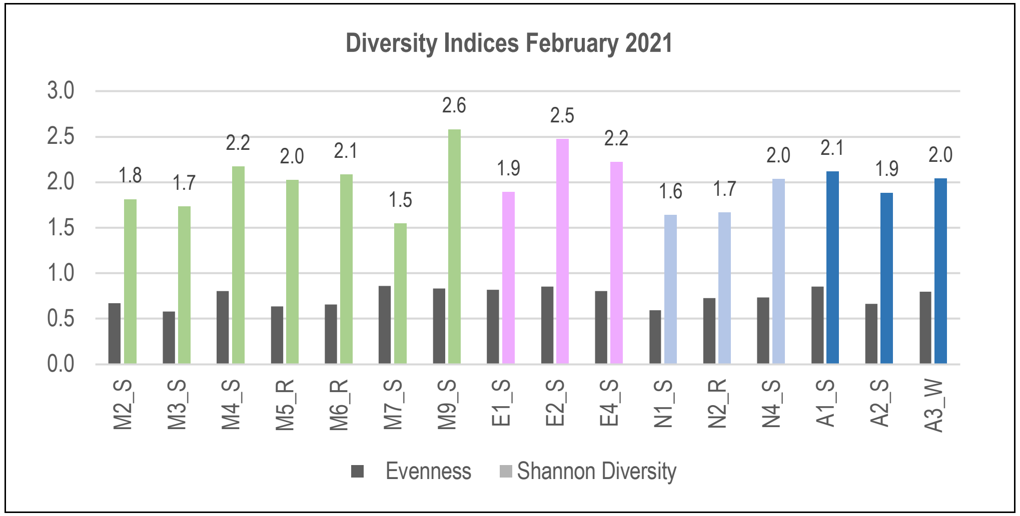

Figure 21: Diversity indices calculated per site, showing the results of Pielou's evenness index and Shannon-Wiener diversity index for the February 2021 survey.

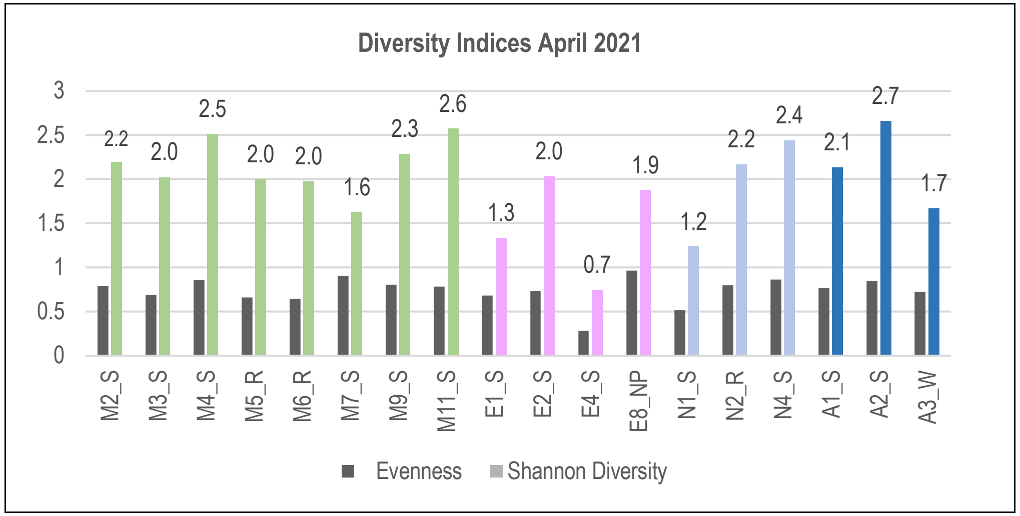

Figure 23: Diversity indices calculated per site, showing the results of Pielou's evenness index and Shannon-Wiener diversity index for the April 2021 survey.

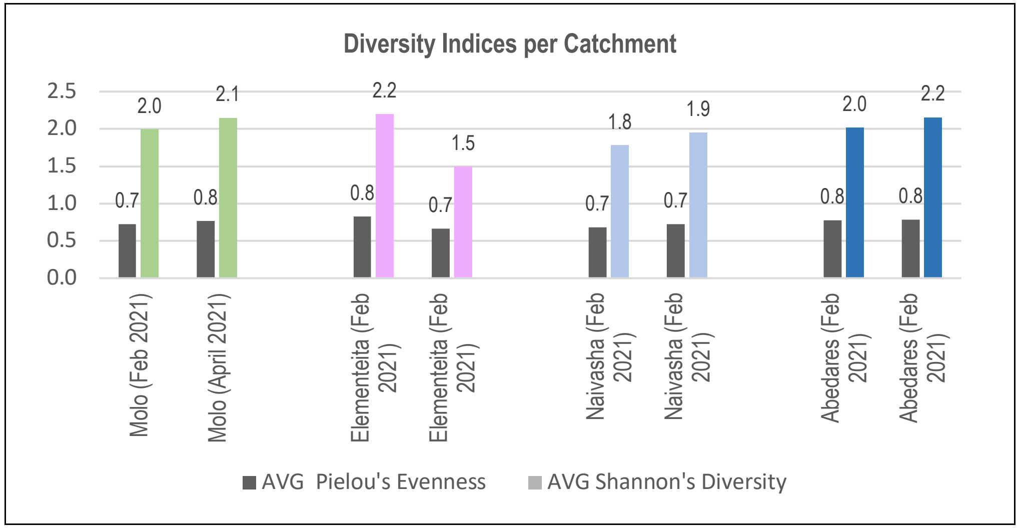

Figure 22: Diversity indices calculated as an average per catchment, showing the results of Pielou's evenness index and Shannon-Wiener diversity index for the February and April 2021 surveys.

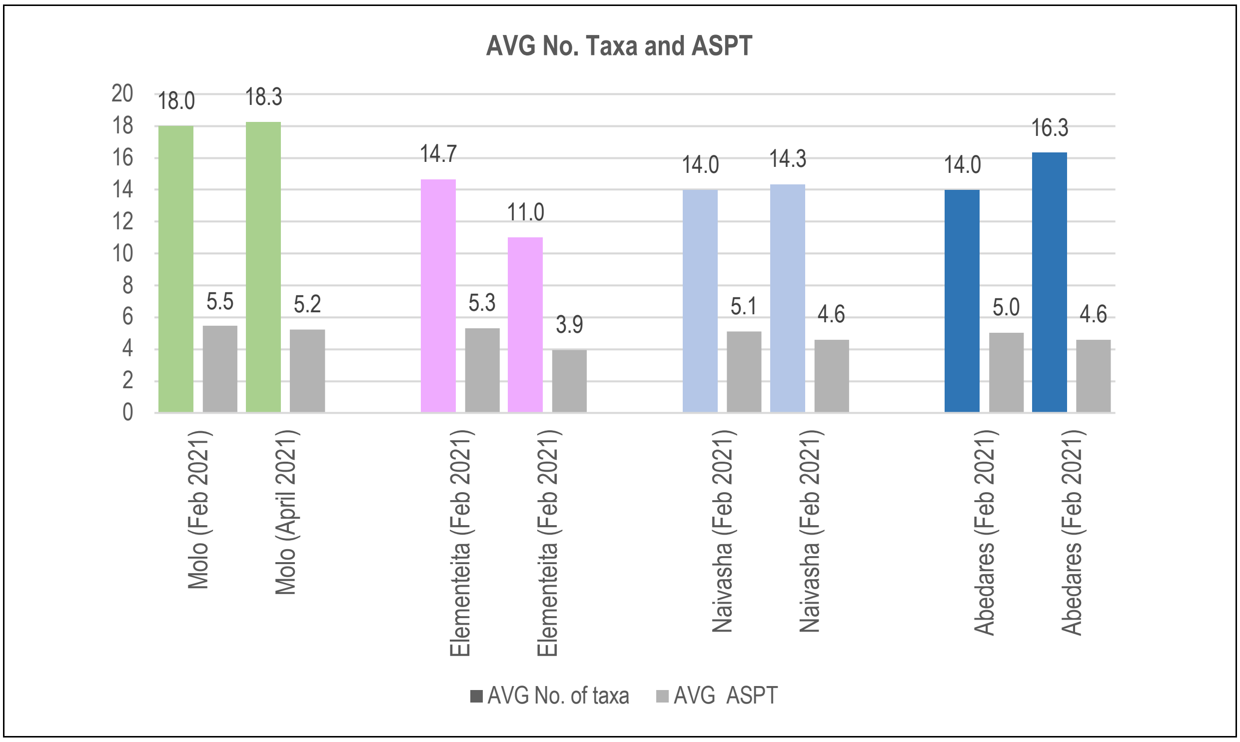

Figure 24: Average score per taxon (ASPT) and average number of macroinvertebrate families per catchment

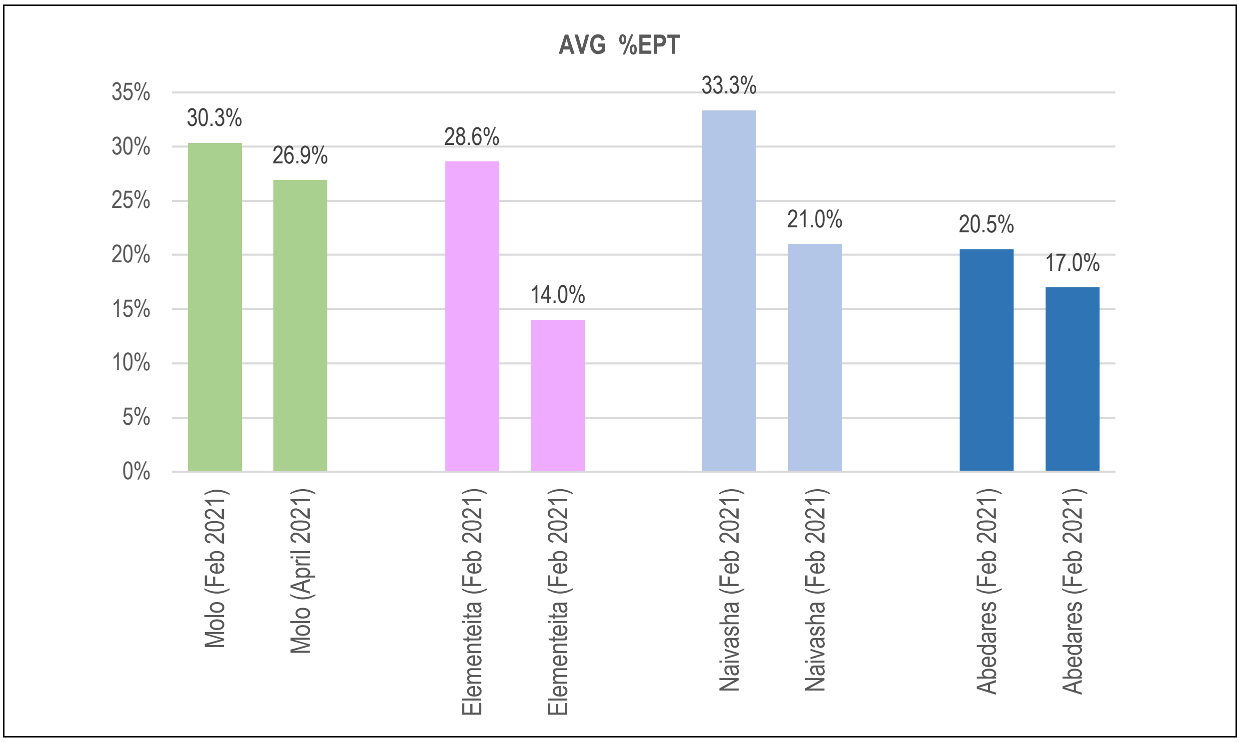

Figure 25: Average percentage Ephemeroptera-Plecoptera-Trichoptera index (%EPT) scores per catchment

5.6.2. Macroinvertebrate Critical Habitat Assessment

The Critical Habitat Assessment (TBC, 2018) identified *Bulinus permembranaceus* as a potential priority species based on Criterion 1 and 2 of IFC PS6. The initial regional assessment area delineated in the CHA contained a large proportion of the range of this Vulnerable restricted range species. The species is found in pools and small streams between 1940 to 2760 masl in the Aberdare Range, Kinangop Plateau and Mau Escarpment in Mau Narok, Molo and Kipkabus (Brown, 1994).

Bulinus species were sampled at various sites in the study area in the February and April 2021 baseline studies (Figure 26). The species sampled are either *Bulinus tropicus* (LC) or less likely *B. permembranaceus,* however molecular work would be required to verify the species. As these species were sampled at higher altitudes, the species could possibly be *B. permembranaceus,* however, the Vulnerable species is not likely to be up listed in status to Endangered due to the road works, and therefore does not qualify under Criterion 1 of the PS6. The direct area of impact of the Project also does not encompass more that 10% of the range of *B. permembranaceus,* and therefore is highly unlikely to qualify under Criterion 2 for Critical Habitat.

Figure 26: *Bulinus* species sampled during the baseline surveys.

5.7. Fish Assessment

5.7.1. Fish Diversity

The species accumulation curve based on Sobs (observed) and expected (Chao1 and Jacknife 1) which considers the observed and mean value of accumulation of species over the samples respectively, showed that the observed totals provide a realistic indication of the thoroughness and general coverage of the study site, where the accumulation curve is approaching saturation (Figure 27). Based on species estimations as shown by the Chao1 and Jacknife1 between 85 and 95% of expected species have been sampled in the local study area which is considered as sufficient sampling effort (Moreno & Halffter, 2000).

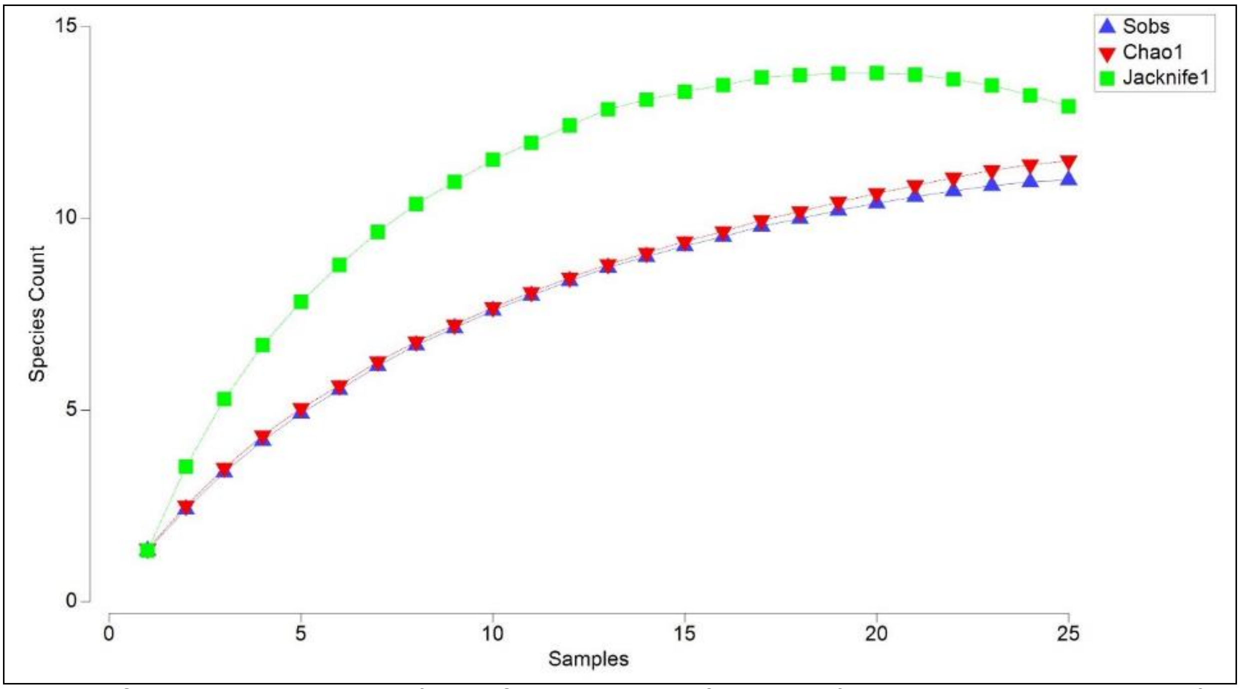

Figure 27: Species accumulation curves of actual (Sobs) and expected (Chao1, Jacknife 1) species data over sites sampled for the 2021 surveys of aquatic systems along the Mau to Rironi route.

Eleven (11) species of fish in five families were sampled in the various habitat types in the 2021 surveys (Table 19; **Appendix H**). Four species were exotic species, representing 36%of the total fish community (*Cyprinus carpio, Gambusia affinis, Poecilia reticulata* and *Oncorhynchus mykiss*) which include habitat modifying and competitive predatory species which affect natural fish communities.

Fish diversity was highest in the Molo and Naivasha catchments, however, was still low overall (Figure 28). The fish communities were mostly dominated by 1 species in high numbers, as is indicated by the evenness values (Figure 28 & Figure 30).

Fish species richness was generally low across all catchments regardless of season. Fish species richness was highest at site N2_R on the Malewa River in April 2021, but on average the Molo catchment showed the highest species richness in terms of fish (Figure 29). Interesting, the headwater sites of the Molo catchment produced no species of fish despite good habitat availability and hydrology. The reason for this is not clear but may be due to several water control weirs along the upper course of the river that block movement of fishes up to the headwaters of the system.

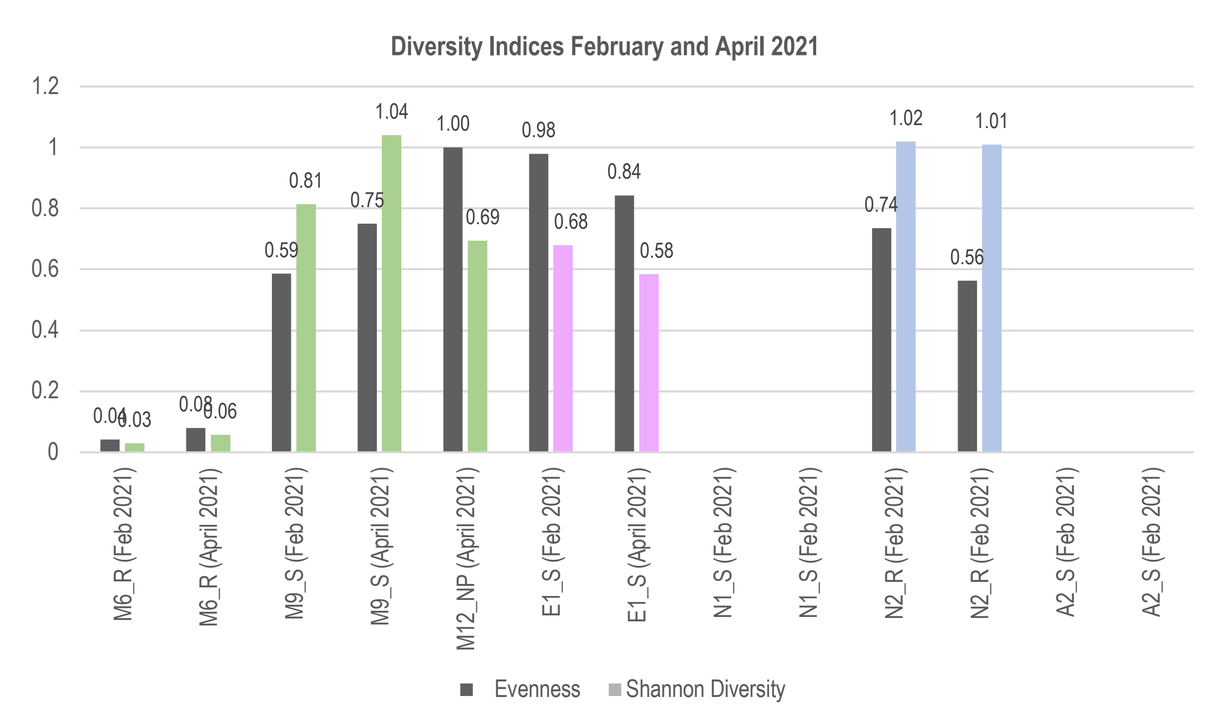

Figure 28: Fish diversity and evenness for sites in the February and April 2021 surveys

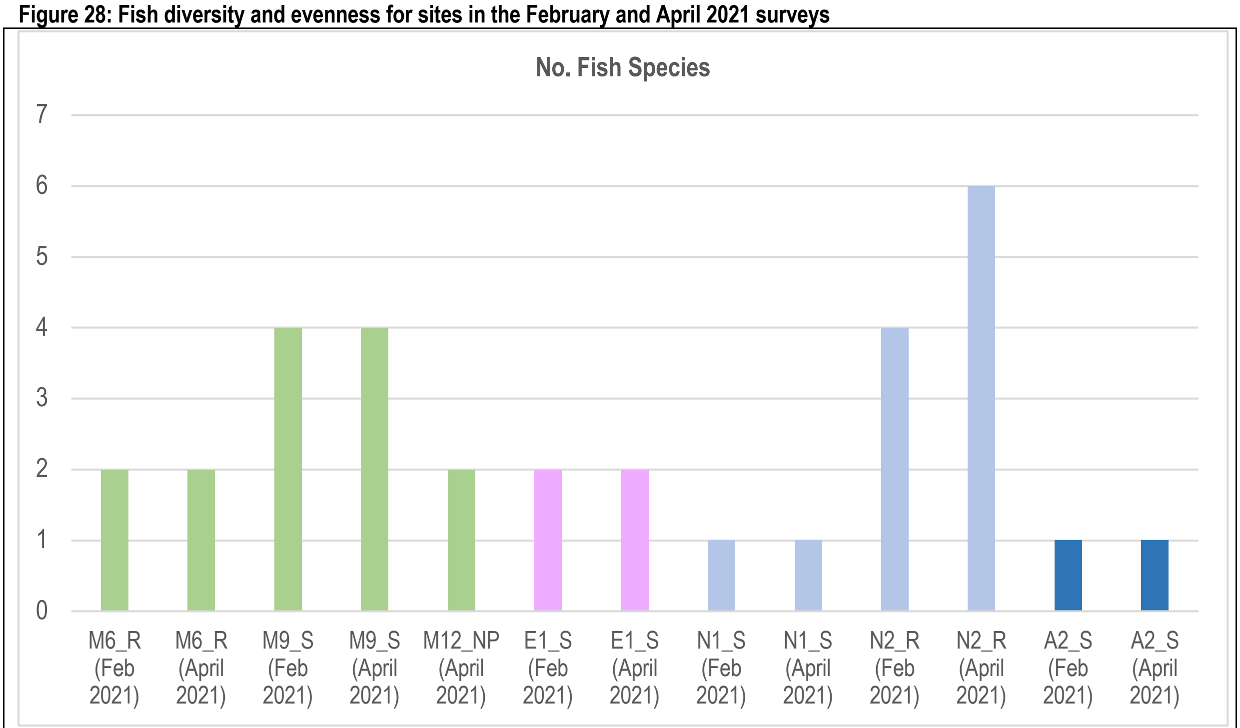

Figure 29: Fish species richness per site for the February and April 2021 surveys

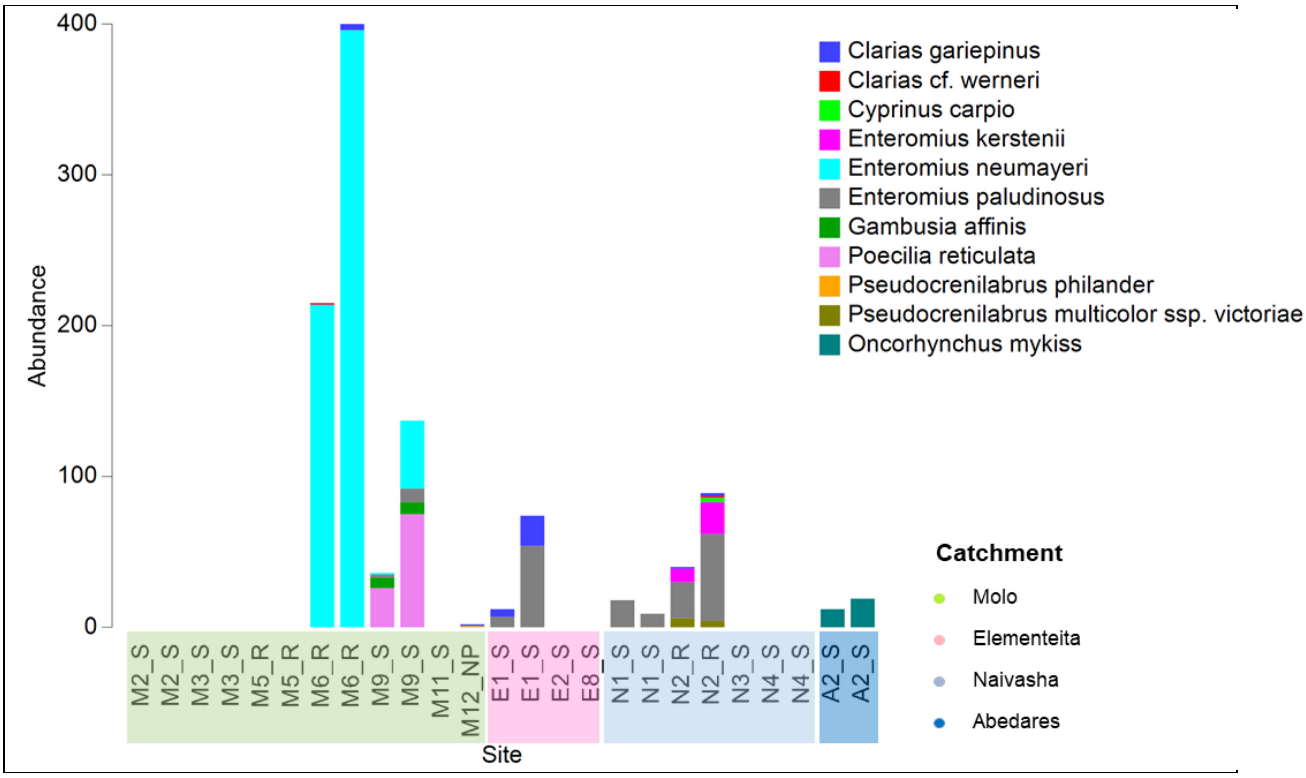

Figure 30: Fish abundance per sampled site showing catchments.

5.7.2. Community Structure

The Molo catchment was strongly associated with invasive poecilids at site M9_S (Rongai River). The Malewa River at site N2_R has a fish community dominated by *Cyprinus carpio, Enteromius* species and *Pseudocrenilabrus multicolor* ssp. *victoriae*. The Molo catchment and the Aberdares sites were clustered close together but with distinctly different fish communities and branches where invasive rainbow trout were associated with the Aberdares. Lake Elementeita was strongly associated with, and differentiated from the other catchments, by an abundance of *Clarias gariepinus* (Figure 29).

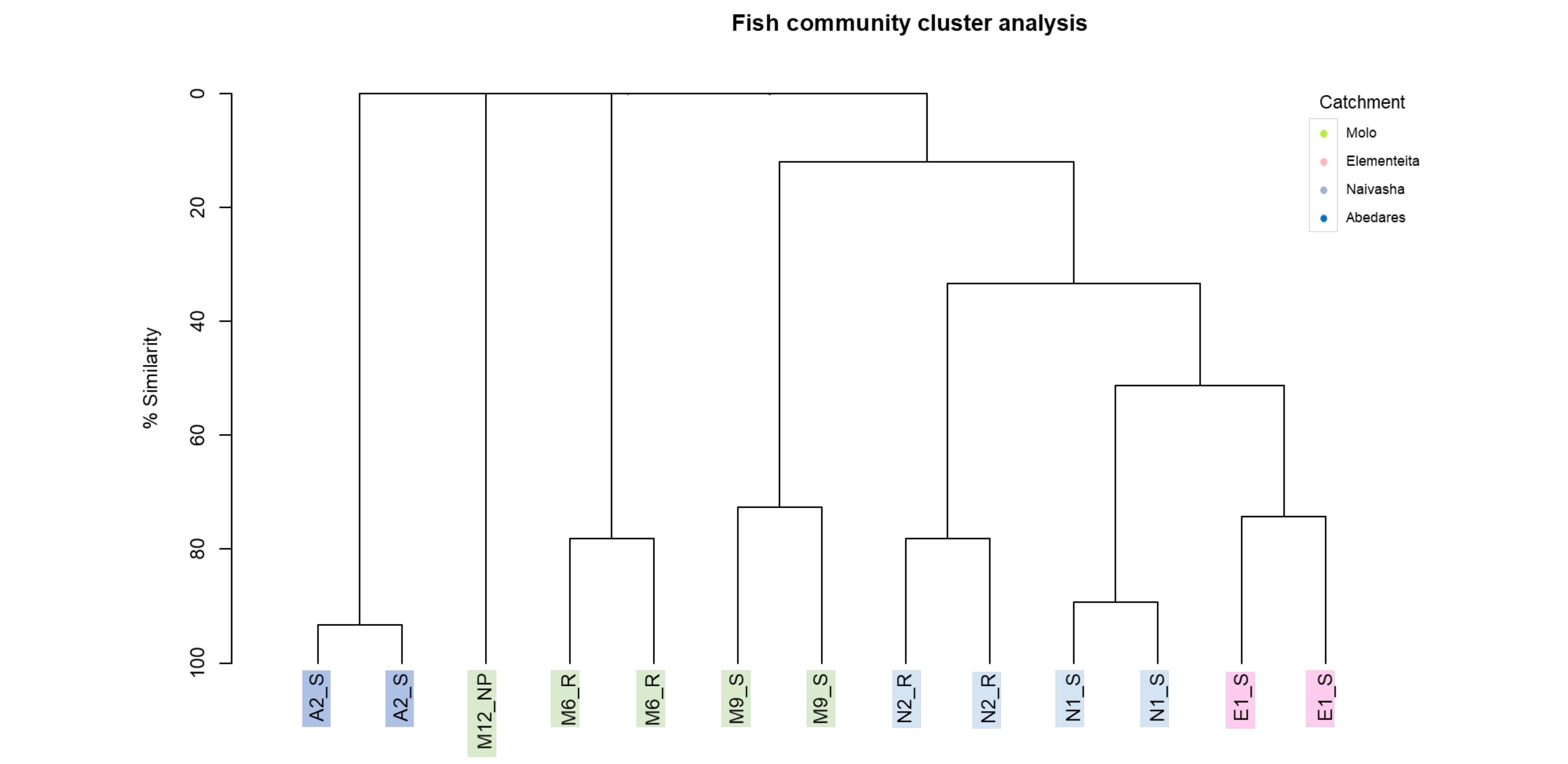

Figure 31: Cluster analysis of fish communities sampled at sites in the study area over both baseline surveys.

5.7.1. Fish Critical Habitat Assessment

No fish species sampled met the thresholds for Critical Habitat under Criterion 1 – 3 of the PS6 as noted in Section 4.2.6 (IFC, 2012; IFC, 2019 - Table 19). All species of fish sampled in this survey are LC according to the IUCN Red List and relatively widely distributed. The *Clarias* and *Enteromius* species are freshwater migrants, however, these species are unlikely to meet the >1% threshold for migratory species as they are widely distributed and common in the greater study area.

The Critical Habitat Assessment (TBC, 2018) identified *Lacustricola* (previously *Aplocheilichthys)* sp. nov. Baringo and *Labeo victorianus* as potential Critical Habitat species based on the overlap with the regional assessment area. Neither of these species were sampled in the baseline surveys.

Lacustricola sp. nov. Baringo inhabits the Lake Baringo catchment, whose headwaters (Molo River) arise on the western rim of the Rift Valley, around the end of the Project Road alignment near Mau Summit. The species is Critically Endangered and was identified as potentially qualifying under Criterion 1 (IFC, 2012). *Aplocheilichthys* sp. nov Baringo was collected in 1969 in an inventory of the fish fauna of Lake Baringo (Mann, 1971; Ssentongo, 1974). The second registered collection was by the German ichthyologist L. Seegers in 1983 (Seegers, 1997). Previously all Procatopodidae were assigned to the genus *Aplocheilichthys* Bleeker, 1863. At present the genus is monotypic containing only *A. spilauchen* (Dumeril, 1861) and *A*. spec. Lake Baringo is now assigned to the genus *Lacustricola*. SSentongo (1974) listed several collection sites, namely large slow flowing sections of The Molo River and tributaries and the swampy parts of Lake Baringo.

- At the fringes of Lake Baringo itself in stagnant swampy pools at the south and east side of the Lake;
- In the Perkerra River, a left bank tributary of the Molo River that flows into the lake at its southern most point.
- In the Molo River just south of the Perkerra crossing;
- Downstream the Molo River at Longumkum.

Based on the locality of these sampling points and the preference of the species for slow flowing and lentic habitat, it was not sampled in the study area as the Molo River along the road alignment does not contain suitable habitat for the species.

Labeo victorianus, locally known as Ningu, is as an endemic cyprinid of the Lake Victoria basin. This species is endemic to the Lake Victoria drainage (Seegers et al., 2003). It occurs in shallow, inshore waters of Lake Victoria (Van Oijen, 1995) and affluent rivers such as the Nzoia (Whitehead, 1959; Corbet, 1961, Cadwalladr, 1965) and Yala (Whitehead,1959) rivers which have their headwaters in the western section of the study area. *Labeo victorianus* is a Critically Endangered species and overlaps in its distribution significantly with the greater regional assessment area, however, does not overlap significantly with the direct footprint of the project. The headwaters of the Yala River draining into the Lake Victoria catchment (west section of the road alignment) are in the species range, however the Yala catchment in the study area is highly degraded and most tributaries were dry in both surveys. The species is a potamodromous species, ascending both large rivers and streams during the rainy season (Fryer and Whitehead 1959) to spawn. Spawning grounds are flooded grasslands beside both permanent and temporary streams (Eccles 1992). The many impacts of bridges and degraded habitat sections on the Yala River would suggest that the species is unlikely to migrate far up the systems within proximity of the Project study area.

Table 19: Summary of fish species sampled in the study area over the various catchments with the results of the assessment of Critical Habitat qualifying features (IFC, 2012). Details of fish sampled per site can be found in Appendix H.

	IUCN Red List Status (IUCN, 2021)	IFC Criterion 1 CR or EN species	IFC Criterion 2 Range restricted	IFC Criterion 3 Migratory	Molo	Lake Elementeita	Lake Naivasha	Aberdares
SILURIFORMES								
Clariidae (2)								
Clarias gariepinus	LC	No	No	No	4	25	3	
Clarias cf. *werneri*	LC	No	No	No	1		1	
CYPRINIFORMES								
Cyprinidae (4)								
Cyprinus carpio	Exotic	-	-	-			3	
Enteromius kerstenii	LC	No	No	No			30	
Enteromius neumayeri	LC	No	No	No	656			
Enteromius paludinosus	LC	No	No	No	11	61	109	
CYPRINODONTIFORMES								
Poeciliidae (2)								
Gambusia affinis	Exotic	-	-	-	15			
Poecilia reticulata	Exotic	-	-	-	101			
PERCIFORMES								
Cichlidae (2)								
Pseudocrenilabrus philander	LC	No	No	No				
Pseudocrenilabrus multicolor ssp. victoriae	LC	No	No	No			10	
SALMONIFORMES								
Salmonidae (1)								
Oncorhynchus mykiss	Exotic	-	-	-				31

Notes:
CR = Critically Endangered; **EN** = Endangered; **LC** = Least Concern
A description of the IFC PS6 criteria thresholds is noted in Section 4.2.6

6. Expert Statement on The Probable Level of Impact from The Road

The aim of the freshwater specialist study was to define baseline freshwater ecological conditions for the study area and to identify sensitive habitats and priority species that may qualify as Critical Habitat. The ecological findings show that the area is in a moderately to largely transformed state, with an overall low freshwater sensitivity. No freshwater Critical Habitat qualifying features are present in the study area, and the area is comprised of a matrix of Natural and Modified Habitat. All fish species identified in the study area are widespread in the Freshwater Ecoregion, with a large component of the community comprising of exotic species.

The proposed nature of the road upgrade would likely have a high impact in the direct project footprint of the road construction, which will dissipate relatively quickly downstream if the correct mitigation measures are put in place to control sediment inputs, decrease water quality impacts, and maintain connectivity in the construction period. It is also considered feasible to reinstate the rivers to their pre-existing condition to attain NNL in Natural Habitat. Whilst the impact is high on the aquatic systems, the duration is relatively short and the options for reinstatement are good, so impacts can be mitigated in a manner that no residual impacts exist after the reinstatement.

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Appendix A-1 – Methods applied at various sites

February and April, 2021

Table 1: Check list of sites and freshwater methods applied at each site, February 2021

Site	*In situ*	Laboratory WQ	IHI	IHAS	FHAS	Diatoms	Macroinvertebrates	Fish
Yala River								
Y1_NP			X					
Y2_NP	X		X					
Molo River								
M1_NP	X		X					
M2_S	X		X	X	X		X	X
M3_S	X	X	X	X	X		X	X
M4_S	X		X	X			X	
M5_R	X		X	X	X		X	X
M6_R	X	X	X	X	X	X	X	X
M7_S	X		X	X			X	
M8_NP			X			X		
M9_S	X	X	X	X	X	X	X	X
M10_W			X					
M11_S			X					
M12_NP			X					
Lake Elementeita								
E1_S	X	X	X	X	X	X	X	X
E2_S	X	X	X	X		X	X	
E3_NP			X			X		
E4_S	X	X	X	X			X	
E5_NP			X					
E8_S	X	X	X					
E8_NP			X					
E10_S			X					
Lake Naivasha								
N1_S	X	X	X	X	X	X	X	X
N2_R	X	X	X	X	X	X	X	X
N3_S	X		X					
N4_S	X		X	X	X		X	X
N5_NP			X					
N6_NP			X					
N7_NP			X					
N8_NP			X					
Rift Valley								
R1_S			X					
R2_S			X					
R3_S			X					
R4_S			X					
Abedares								
A1_S	X		X	X			X	
A2_S	X	X	X	X	X	X	X	X

Site	*In situ*	Laboratory WQ	IHI	IHAS	FHAS	Diatoms	Macroinvertebrates	Fish
A3_W	X		X	X			X	
A4_W	X		X					
A5_W	X		X					
A6_S	X		X					

Table 2: Check list of sites and freshwater methods applied at each site, April 2021

Site	*In situ*	Laboratory WQ	IHI	IHAS	FHAS	Diatoms	Macroinvertebrates	Fish
Yala River								
Y1_NP			X					
Y2_NP	X		X					
Molo River								
M1_NP	X		X					
M2_S	X		X	X	X		X	X
M3_S	X	X	X	X	X	X	X	X
M4_S	X		X	X			X	
M5_R	X		X	X	X		X	X
M6_R	X	X	X	X	X	X	X	X
M7_S	X		X	X			X	
M8_NP			X					
M9_S	X	X	X	X	X	X	X	X
M10_W	X		X			X		
M11_S	X		X	X	X	X	X	X
M12_NP	X		X		X			X
Lake Elementeita								
E1_S	X	X	X	X	X	X	X	X
E2_S	X	X	X	X	X		X	X
E3_NP			X					
E4_S	X	X	X	X		X	X	
E5_NP			X					
E8_S	X	X	X	X	X	X	X	X
E8_NP			X					
E10_S	X		X					
Lake Naivasha								
N1_S	X	X	X	X	X	X	X	X
N2_R	X	X	X	X	X	X	X	X
N3_S	X		X		X			X
N4_S	X		X	X	X		X	X
N5_NP			X					
N6_NP	X		X					
N7_NP			X					
N8_NP			X					
Rift Valley								
R1_S	X		X					
R2_S	X	X	X			X		
R3_S	X		X					
R4_S	X		X					
Abedares								
A1_S	X		X	X		X	X	

Site	*In situ*	Laboratory WQ	IHI	IHAS	FHAS	Diatoms	Macroinvertebrates	Fish
A2_S	X	X	X	X	X	X	X	X
A3_W	X		X	X			X	
A4_W	X		X					
A5_W	X		X			X		
A6_S	X		X					

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Appendix B – Water Quality Baseline Data
February and April, 2021

Table 1: ***In situ*** **water quality data for sites sampled in the Yala River basin, February and April 2021 – values highlighted in red show exceeded limits as per DWAF (1996) freshwater ecosystem targets**

	Yala River			
	Y1_NP		Y2_NP	
	Feb-21	Apr-21	Feb-21	Apr-21
pH	No water	No water	7.88	7.48
EC (µscm)	No water	No water	262	386
TDS (ppm)	No water	No water	186	273
Temperature (˚C)	No water	No water	17.5	15.3
Time	No water	No water	10:41	09:42
Turbidity (NTUs)	No water	No water	316	974
Colour	No water	No water	Silty	Silty

Table 2: ***In situ*** **water quality data for sites sampled in the Molo River basin, February and April 2021 – values highlighted in red show exceeded limits as per DWAF (1996) freshwater ecosystem targets**

	Molo River																
	M1_NP		M2_S		M3_S		M4_S		M5_R		M6_R		M7_S		M9_S		M10_W	M11_S	M12_NP
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Apr-21	Apr-21
pH	6.94	7.76	8.11	7.61	7.62	7.48	7.65	7.73	7.63	7.76	7.49	7.71	7.65	8.54	7.61	7.66	7.37	7.22	7.05
EC (µscm)	336	434	126.7	124.3	296	349.7	242	253	180.2	190.2	263	270	392	448	338	449	184.2	219	298
TDS (ppm)	242	309	89	88	206	231	172	171	108	136	186	190	275	320	240	319	131	155	210
Temperature (˚C)	18.0	17.9	17.0	17.0	16.1	19.8	16.1	19.1	16.1	19.8	17.2	19.4	21.1	23.6	17.1	19.4	21.9	16.3	17.7
Time	10:09	10:09	11:47	11:00	08:47	13:21	12:35	14:15	13:54	15:10	08:30	10:40	15:41	15:01	08:13	15:23	13 30	10:55	09:03
Turbidity (NTUs)	105	205	79	74	36	35	28	17.3	24.55	33	22.96	28.95	186	100	45.06	40	69	45	35
Colour	Silty	Silty	Silty	Silty	Opaque	Silty	Clear	Clear	Clear	Silty	Clear	Silty	Opaque	Silty	Silty	Silty	Silty	Silty	Clear

Table 3: ***In situ*** **water quality data for sites sampled in the Lake Elementeita basin, February and April 2021 – values highlighted in red show exceeded limits as per DWAF (1996) freshwater ecosystem targets**

	Lake Elementeita								
	E1_S		E2_S		E4_S		E8_S		E10_S
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21
pH	7.72	7.51	7.86	7.81	7.65	7.59	7.67	7.46	7.71
EC (µscm)	222	290	454	509	242	692	266	379	401
TDS (ppm)	157	200	332	384	172	490	188	268	284
Temperature (˚C)	16.7	18.4	18.1	19.4	16.1	18.4	17.5	17.7	15
Time	10:42	11:11	14:12	13:58	12:35	09:00	09:53	09:50	08:55
Turbidity (NTUs)	110	109	33.2	102	28.06	35.5	80	34.5	28.5
Colour	Silty	Silty	Discoloured	Discoloured	Clear	Clear	Silty	Silty	Silty

Table 4: ***In situ*** **water quality data for sites sampled in the Lake Naivasha basin, February and April 2021 – values highlighted in red show exceeded limits as per DWAF (1996) freshwater ecosystem targets**

	Lake Naivasha								
	N1_S		N2_R		N3_S		N4_S		N6_NP
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21
pH	7.61	7.57	7.28	7.13	7.18	6.06	7.54	7.2	7.29
EC (µscm)	265	242	178	208	292	1713	242	247	184
TDS (ppm)	188	173	127	147	208	1210	172	192	132
Temperature (˚C)	19.2	21.4	18.4	20.8	19.2	17.2	16.4	18.4	16.5
Time	11:00	13:37	09:30	09:27	10:39	09:51	10:31	11:00	08:26
Turbidity (NTUs)	89	166	80	89	359	21.7	317	255	881
Colour	Silty	Silty	Silty	Silty	Silty	Clear	Silty	Silty	Silty

Table 5: *In situ* water quality data for sites sampled in the Rift Valley basin, February and April 2021 – values highlighted in red show exceeded limits as per DWAF (1996) freshwater ecosystem targets

	Rift Valley			
	R1_S	**R2_S**	**R3_S**	**R4_S**
	Apr-21	**Apr-21**	**Apr-21**	**Apr-21**
pH	7.55	8.23	8.13	8.21
EC (µscm)	896	278	804	277
TDS (ppm)	633	197	564	196
Temperature (˚C)	23.2	18.3	22.6	18.9
Time	14:10	14:38	15:10	15:27
Turbidity (NTUs)	19.62	209	175	432
Colour	Clear	Silty	Silty	Silty

Table 6: *In situ* water quality data for sites sampled in the Abedares basin, February and April 2021 – values highlighted in red show exceeded limits as per DWAF (1996) freshwater ecosystem targets

	Abedares									
	A1_S		**A2_S**		**A3_W**		**A4_W**		**A5_W**	**A6_S**
	Feb-21	**Apr-21**	**Feb-21**	**Apr-21**	**Feb-21**	**Apr-21**	**Feb-21**	**Apr-21**	**Apr-21**	**Apr-21**
pH	6.97	7.26	7.12	7.51	7.03	7.1	7.51	7.05	7.21	7.05
EC (µscm)	115.4	114.7	66.6	65.6	98.7	114	141.7	164.1	383	145.9
TDS (ppm)	82.0	80.9	47.8	46.5	68.7	82	105	116	270	104
Temperature (˚C)	12.8	16.23	13.9	16.0	16.6	17.9	15.2	17.8	18	16.1
Time	09:00	13:20	13:00	12:30	09:55	11.30	09:00	10:29	08:55	10:10
Turbidity (NTUs)	37	20.3	11.96	10.7	12.9	8.39	258	44.52	19	15.5
Colour	Opaque	Clear	Clear	Clear	Clear	Clear	Silty	Silty	Clear	Clear

Table 7: Laboratory water quality data for sites sampled in the Molo and Elemeneteita basins, February and April 2021

Analyte Name	Units	Molo River						Lake Elementeita							
		Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21
		M3_S		M6_R		M9S		E1_S		E2_S		E4_S		E8_8	
Sum of Anions	meq/l	2.32	2.63	2.26	2.24	2.79	3.53	1.99	2.3	3.92	4.32	5.61	5.37	2.39	3.14
Sum of Cations	meq/l	2.51	2.81	2.24	2.41	2.99	3.87	2.02	2.64	4.19	4.76	6.57	6.09	2.45	3.53
Anion-Cation Balance	%	3.95	3.44	-0.35	3.68	3.48	4.64	0.7	6.98	3.27	4.84	7.94	6.22	1.25	5.85
Acidity as CaCO3	mg/l	15	10	15	<10	15	15	15	15	15	15	15	20	15	10
M Alkalinity as CaCO3	mg/l		80		70		110		95		170		240		130
P Alkalinity as CaCO3	mg/l		<12		<12		<12		<12		<12		<12		<12
Total Alkalinity as CaCO3	mg/l	65	80	70	70	90	110	75	95	151	170	251	240	95	130
Calcium	mg/l	11	14	8.4	10	7.8	13	7.5	13	19	24	16	20	9.4	14
Iron	mg/l	0.24	0.48	0.2	0.43	1.1	0.6	1.8	1	0.32	0.14	0.63	0.51	1.7	1.3
Potassium	mg/l	14	16	13	13	18	26	13	15	24	25	31	28	14	18
Magnesium	mg/l	2.7	3.4	2.2	2.7	2	3.3	1.8	2.9	4.5	5.5	2.4	2.8	2.3	3.3
Sodium	mg/l	32	33	30	31	44	52	25	31	52	56	110	95	31	47
Tellurium	mg/l	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Aluminium	mg/l	0.16	0.32	0.32	0.4	0.79	0.44	8.5	0.92	0.2	0.086	0.34	0.2	6.6	5.8
Arsenic	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.002	0.001	<0.0005	<0.0005
Boron	mg/l	0.002	0.005	0.002	0.004	<0.002	0.007	<0.002	0.006	0.005	0.007	0.007	0.007	0.004	0.006
Barium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Beryllium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	mg/l	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/l	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Chromium	mg/l	0.004	0.006	0.004	0.005	0.004	0.007	0.003	0.008	0.009	0.012	0.015	0.014	0.004	0.01
Copper	mg/l	0.001	<0.0009	<0.0009	<0.0009	<0.0009	0.001	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009
Manganese	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.01	<0.002	0.002

Analyte Name	Units	Molo River						Lake Elementeita							
		Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21
		M3_S		M6_R		M9S		E1_S		E2_S		E4_S		E8_8	
Molybdenum	**mg/l**	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.004	0.003	0.001	0.001
Lead	**mg/l**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nickel	**mg/l**	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Antimony	**mg/l**	<0.01		<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	
Selenium	**mg/l**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Strontium	**mg/l**	0.025	0.029	0.02	0.02	0.013	0.019	0.012	0.022	0.036	0.042	0.021	0.022	0.015	0.024
Thorium	**mg/l**	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Titanium	**mg/l**	0.009	0.017	0.017	0.015	0.042	0.021	0.056	0.045	0.013	0.005	0.022	0.012	0.066	0.056
Thallium	**mg/l**	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Uranium	**mg/l**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.001	0.001	0.001	0.001	<0.0005	<0.0005
Vanadium	**mg/l**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc	**mg/l**	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01
Zirconium	**mg/l**	<0.007	<0.007	<0.007	<0.007	0.013	<0.007	0.014	0.011	<0.007	<0.007	0.007	<0.007	0.017	0.013
Chloride	**mg/l**	19	21	14	16	14	18	9.4	10	23	26	12	12	10	14
Fluoride	**mg/l**	0.22	0.33	0.26	0.32	0.58	0.98	0.39	0.59	0.82	1	5.9	12	0.44	0.78
Nitrite	**mg/l**	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5	<0.5	<0.5	1.2	<0.5
Nitrite as N	**mg/l**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2
Nitrate	**mg/l**	15	13	18	15	21	27	6.8	1.3	3.1	0.9	0.2	0.7	3.9	1
Nitrate as N	**mg/l**	3.4	3	4.1	3.3	4.8	6.1	1.5	0.3	0.69	0.21	0.05	0.15	0.88	0.22
Sulphate	**mg/l**	11	11	7.8	7.6	12	19	5.5	4.8	10	8.5	12	11	5.9	7
Mercury	**µg/l**	0.002	0.002	0.003	0.009	0.003	0.001	0.005	0.009	0.004	0.003	0.01	0.003	0.005	0.012
Ammonia	**mg/l**		0.089		0.026		0.067		0.16		0.28		0.071		0.13
Ammonia as N	**mg/l**		0.07		0.02		0.06		0.13		0.23		0.06		0.11

Above Target Water Quality Requirements (DWAF, 1996)

Above Chronic Target Values (DWAF, 1996)

Analyte Name	Units	Molo River						Lake Elementeita							
		Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21
		M3_S		M6_R		M9S		E1_S		E2_S		E4_S		E8_8	
Above Acute Target Value (DWAF, 1996)															

Table 8: Laboratory water quality data for sites sampled in the Naivasha, Rift Valley and Abedare basins, February and April 2021

Analyte Name	Units	Lake Naivasha				Rift Valley	Abedares	
		Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Feb-21	Apr-21
		N1_S		N2_R		R2_S	A2_W	
Sum of Anions	meq/l	2.31	1.89	1.6	1.75	2.18	0.47	0.56
Sum of Cations	meq/l	2.49	2.28	1.75	2.05	2.33	0.543	0.531
Anion-Cation Balance	%	3.71	9.16	4.5	7.82	3.13	7.15	-2.58
Acidity as CaCO3	mg/l	15	10	15	10	10	<10	<10
M Alkalinity as CaCO3	mg/l		80		70	70		20
P Alkalinity as CaCO3	mg/l		<12		<12	<12		<12
Total Alkalinity as CaCO3	mg/l	101	80	65	70	70	15	20
Calcium	mg/l	12	11	9.9	13	9.1	1.7	1.8
Iron	mg/l	1.5	0.88	3.3	1.8	0.54	0.13	0.19
Potassium	mg/l	14	14	7.2	8.2	12	3.3	3.1
Magnesium	mg/l	2.8	2.3	3	3.6	2.8	0.5	0.51
Sodium	mg/l	29	27	16	19	30	7.6	7.2
Tellurium	mg/l	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Aluminium	mg/l	7.9	15	9.7	12	0.71	0.077	0.13
Arsenic	mg/l	<0.0005	0.001	<0.0005	0.001	<0.0005	<0.0005	<0.0005
Boron	mg/l	0.003	0.005	<0.002	0.006	0.01	0.008	0.006
Barium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Beryllium	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	mg/l	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/l	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Chromium	mg/l	0.006	0.006	0.004	0.007	0.005	<0.002	0.002
Copper	mg/l	<0.0009	0.001	0.001	0.001	<0.0009	<0.0009	<0.0009
Manganese	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Molybdenum	mg/l	0.002	0.002	0.001	0.002	0.001	<0.001	<0.001
Lead	mg/l	<0.0005	<0.0005	<0.0005	0.001	<0.0005	<0.0005	<0.0005
Nickel	mg/l	<0.001		<0.001			<0.001	
Antimony	mg/l	<0.01		<0.01			<0.01	
Selenium	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Analyte Name	Units	Lake Naivasha				Rift Valley	Abedares	
		Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Feb-21	Apr-21
		N1_S		N2_R		R2_S	A2_W	
Strontium	**mg/l**	0.023	0.02	0.032	0.044	0.016	0.012	0.012
Thorium	**mg/l**	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Titanium	**mg/l**	0.061	0.052	0.12	0.11	0.035	0.005	0.006
Thallium	**mg/l**	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Uranium	**mg/l**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium	**mg/l**	<0.0005	<0.0005	<0.0005	0.001	<0.0005	<0.0005	<0.0005
Zinc	**mg/l**	<0.05	<0.01	<0.05	0.03	<0.01	<0.05	<0.01
Zirconium	**mg/l**	0.019	0.015	0.029	0.024	0.01	<0.007	<0.007
Chloride	**mg/l**	7.8	5.9	5.5	6.8	19	3.2	3.1
Fluoride	**mg/l**	0.52	0.71	0.28	0.43	0.45	0.07	0.12
Nitrite	**mg/l**	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrite as N	**mg/l**	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate	**mg/l**	0.3	1.8	1.8	1.5	5.5	3.3	3
Nitrate as N	**mg/l**	0.07	0.41	0.4	0.35	1.2	0.74	0.68
Sulphate	**mg/l**	3.8	4.9	5.4	6.7	8.1	1.2	1.2
Mercury	**µg/l**	0.009	0.008	0.007	0.004	0.003	0.011	0.004
Ammonia	**mg/l**		0.14		0.22	<0.012		0.032
Ammonia as N	**mg/l**		0.12		0.18	<0.01		0.03
Above Target Water Quality Requirements (DWAF, 1996)	(orange)							
Above Chronic Target Values (DWAF, 1996)	(red)							
Above Acute Target Value (DWAF, 1996)	(dark red)							

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Appendix C – Index of Habitat Integrity
Baseline Data
February and April, 2021

Table 1: Index of Habitat Integrity scores for each site in the Yala, Molo and Elementetia catchments in February and April 2021

	Yala River		Molo River												Lake Elementeita						
	Y1_NP	Y2_NP	M1_NP	M2_S	M3_S	M4_S	M5_R	M6_R	M7_S	M8_NP	M9_S	M10_W	M11_S	M12_NP	E1_S	E2_S	E3_NP	E4_S	E5_NP	E8_S	E8_NP
Instream Habitat Integrity																					
Water Abstraction	15	10	10	10	10	5	15	15	15	20	10	10	5	10	5	5	6	5	15	5	5
Flow Modification	20	15	20	10	20	10	10	12	15	15	15	15	12	15	5	5	5	10	15	5	5
Channel Modification	5	20	20	15	9	10	15	10	15	13	15	15	15	10	10	10	7	10	15	8	5
Water Quality	10	10	10	10	12	10	12	12	15	0	10	10	10	7	5	10	10	10	15	8	5
Inundation	10	10	10	10	15	5	15	10	15	15	10	10	10	15	5	5	10	5	15	5	5
Bed Modification	0	15	15	10	7	15	20	13	15	15	10	10	15	9	7	5	10	15	0	8	10
Total (Out Of 150)	60	80	85	65	73	55	87	72	90	78	70	70	67	66	37	40	48	55	75	39	35
Secondary																					
Exotic Macrophytes	0	0	15	0	0	5	0	0	0	0	0	0	9	5	0	0	0	5	0	0	0
Exotic Fauna	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Rubbish Dumping	0	5	20	5	10	5	8	5	10	5	5	5	5	3	0	0	5	5	10	0	0
Total (Out Of 75)	0	5	35	5	10	10	8	5	10	5	15	5	14	8	0	0	5	10	10	0	0
Riparian Zone Habitat Integrity																					
Water Abstraction	20	20	20	15	8	10	5	15	10	15	10	5	10	10	5	10	7	10	20	5	5
Flow Modification	20	20	20	15	10	10	10	15	15	15	15	10	15	10	5	5	7	10	14	5	5
Channel Modification	5	10	20	15	10	10	15	10	15	15	10	15	15	10	5	7	7	10	15	10	5
Water Quality	10	10	15	10	10	10	11	10	15	15	10	10	10	5	5	0	7	10	10	0	5
Inundation	10	10	10	10	5	15	15	10	12	15	10	10	10	10	5	10	7	15	15	10	5
Vegetation Removal	15	20	20	20	8	10	15	15	13	20	15	5	15	10	5	5	5	10	10	10	5
Exotic Vegetation	20	20	20	20	15	15	15	10	15	15	15	15	15	10	10	5	10	15	20	10	8
Bank Erosion	5	17	20	15	12	15	15	10	20	10	17	5	5		5	15	5	15	10	10	10
Total (Out Of 200)	105	127	145	120	78	95	101	95	115	120	102	75	95	65	45	57	55	95	114	60	48
Instream Integrity Score	69.0	58.0	46.0	65.0	61.0	68.0	53.6	61.5	51.4	59.2	59.6	63.0	61.0	64.0	81.0	79.2	74.4	68.0	59.0	80.0	82.0

	Yala River		Molo River												Lake Elementeita						
Integrity Class	C	D	D	C	C	C	D	C	D	D	C	C	C	C	B	B	C	C	D	B	B
Riparian Integrity Score	48.0	36.0	27.0	40.0	61.0	53.0	49.7	52.4	42.2	40.2	48.7	63.0	53.0	68.0	77.6	71.2	72.7	53.0	43.0	70.0	76.0
Integrity Class	D	E	E	D	C	D	D	D	D	D	D	C	D	C	C	C	C	D	D	C	C
Over All IHI %	58.5	47.0	36.5	52.5	61.0	60.5	51.6	56.9	46.8	49.7	54.1	63.0	57.0	66.0	79.3	75.2	73.6	60.5	51.0	75.0	79.0
Over All IHI Category	D	D	E	D	C	C	D	D	D	D	D	C	D	C	C	C	C	C	D	C	B

- A - Natural
- B - Largely Natural
- C - Moderately modified
- D - Largely modified
- E - Seriously modified
- F - Critically modified

Table 2: Index of Habitat Integrity scores for each site in the Naivasha, Rift Valley and Abedare catchments in February and April 2021

	Lake Naivasha								Rift Valley				Abedares					
	N1_S	N2_R	N3_S	N4_S	N5_NP	N6_NP	N7_NP	N8_NP	R1_S	R2_S	R3_S	R4_S	A1_S	A2_S	A3_W	A4_W	A5_W	A6_S
Instream Habitat Integrity																		
Water Abstraction	15	15	15	10	10	10	10	15	0	0	10	5	10	5	10	15	5	5
Flow Modification	10	10	15	10	15	15	15	15	10	10	12	10	5	10	5	15	10	5
Channel Modification	20	15	15	20	15	15	15	15	5	5	12	15	5	10	10	15	10	5
Water Quality	8	5	10	15	10	15	15	10	15	12	15	15	5	5	10	10	10	10
Inundation	15	10	15	5	15	10	15	15	10	0	10	15	10	5	10	15	10	5
Bed Modification	15		15	20	10	10	15	20	10	5	10	15	5	7	10	15	10	10
Total (Out Of 150)	83	55	85	80	75	75	85	90	50	32	69	75	40	42	55	85	55	40
Secondary																		
Exotic Macrophytes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exotic Fauna	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Rubbish Dumping	0	0	0	5	10	15	15	10	15	15	15	12	10	0	0	3	5	5
Total (Out Of 75)	0	0	0	5	10	15	25	10	15	15	15	12	10	0	0	3	5	5
Riparian Zone Habitat Integrity																		
Water Abstraction	15	0	15	5	7	10	10	15	5	0	10	5	15	10	15	15	10	5
Flow Modification	15	0	10	5	10	15	15	15	5	10	10	15	15	10	15	15	12	10
Channel Modification	10	0	15	15	15	10	15	20	10	10	15	12	10	10	10	15	10	10
Water Quality	7	0	15	15	10	10	15	15	10	10	12	10	10	10	10	10	10	10
Inundation	15	0	15	5	10	10	15	14	5	0	7	15	5	10	5	5	10	5
Vegetation Removal	15	0	15	9	10	15	15	20	10	10	10	10	10	15	10	15	8	5
Exotic Vegetation	15	0	10	15	15	10	15	15	10	5	10	10	15	15	15	10	10	5
Bank Erosion	20	0	20	5	20	20	20	15	10	10	10	15	3	5	8	5	0	10
Total (Out Of 200)	112	0	115	74	97	100	120	129	65	55	84	92	83	85	88	90	70	60
Instream Integrity Score	57.7	72.0	57.0	57.0	60.0	58.0	50.0	52.0	71.0	79.0	61.0	59.0	77.4	78.4	71.8	55.9	71.0	78.0
Integrity Class	D	C	D	D	C	D	D	D	C	C	C	D	C	C	C	D	C	C
Riparian Integrity Score	43.8	100.0	42.0	63.0	51.0	49.0	40.0	35.0	67.0	72.0	58.0	54.0	58.7	57.8	55.9	55.0	66.0	70.0

	Lake Naivasha								Rift Valley				Abedares					
Integrity Class	D	A	D	C	D	D	D	E	C	C	D	D	D	D	D	D	C	C
Over All IHI %	50.7	86.0	49.5	60.0	55.5	53.5	45.0	43.5	69.0	75.5	59.5	56.5	68.1	68.1	63.9	55.4	68.5	74.0
Over All IHI Category	D	B	D	C	D	D	D	D	C	C	D	D	C	C	C	D	C	C
A - Natural																		
B - Largely Natural																		
C - Moderately modified																		
D - Largely modified																		
E - Seriously modified																		
F - Critically modified																		

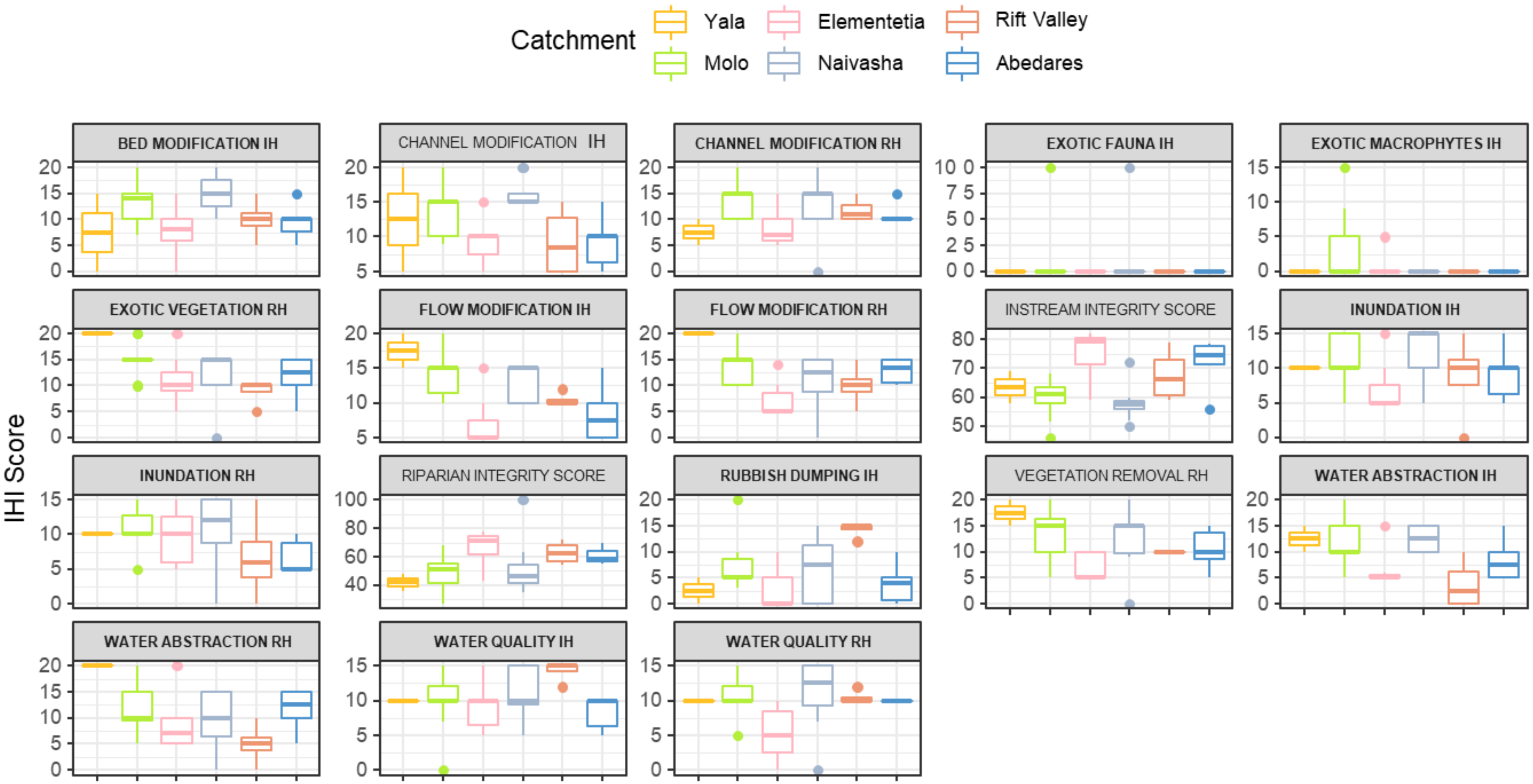

Figure 1: Box plots with average values for each habitat modification metric scored in the IHI, including Standard Deviation for each catchment assessed

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Appendix D – Macroinvertebrate Habitat Baseline Data
February and April, 2021

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Table 1: Invertebrate Habitat Assessment (IHAS) scores for each site in the Molo and Elementetia catchments in February and April 2021

	Molo																Lake Elementeita						
	M2_S		M3_S		M4_S		M5_R		M6_R		M7_S		M9_S		M11_S	M12_NP	E1_S		E2_S		E4_S		E8_S
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Feb-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21
Stones In Current (SIC)	21	17	5	18	14	9	14	15	25	24	0	0	18	13	9	22	0	0	16	7	5	5	0
Vegetation	6	17	14	9	9	15	9	10	13	11	6	5	14	8	18	0	11	8	0	0	14	11	0
Other Habitat (OH)	20	18	21	20	19	20	19	21	18	21	10	9	22	21	17	28	24	20	18	18	21	14	10
Habitat Total	47	52	40	47	42	44	42	46	56	56	16	14	54	42	44	50	35	28	34	25	40	30	10
IHAS Score	67	69	63	63	53	59	56	61	75	75	21	19	72	56	59	72	47	37	45	33	53	40	13
	Adequate	Adequate	Adequate	Adequate	Poor	Poor	Poor	Adequate	Adequate	Adequate	Poor	Poor	Adequate	Poor	Poor	Adequate	Poor	Poor	Poor	Poor	Poor	Poor	Poor

>80 %	Good	>80 %
60-79%	Adequate	60-80 %
<69 %	Poor	<60%

Table 2 Invertebrate Habitat Assessment (IHAS) scores for each site in the Naivasha and Abedare catchments in February and April 2021

	Lake Naivasha								Abedares					
	N1_S		N2_R		N3_S		N4_S		A1_S		A2_S		A3_W	
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21
Stones In Current (SIC)	22	14	0	0	0	10	23	0	0	0	17	0	0	0
Vegetation	0	0	13	14	11	13	14	14	16	14	16	0	17	18
Other Habitat (OH)	28	21	20	17	12	13	12	18	9	12	21	0	11	11
Habitat Total	50	35	33	31	23	36	49	32	25	26	54	0	28	29
IHAS Score	67	47	44	41	31	48	65	43	33	35	72	0	37	39
	Adequate	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor
>80 %	Good													
60-79%	Adequate													
<69 %	Poor													

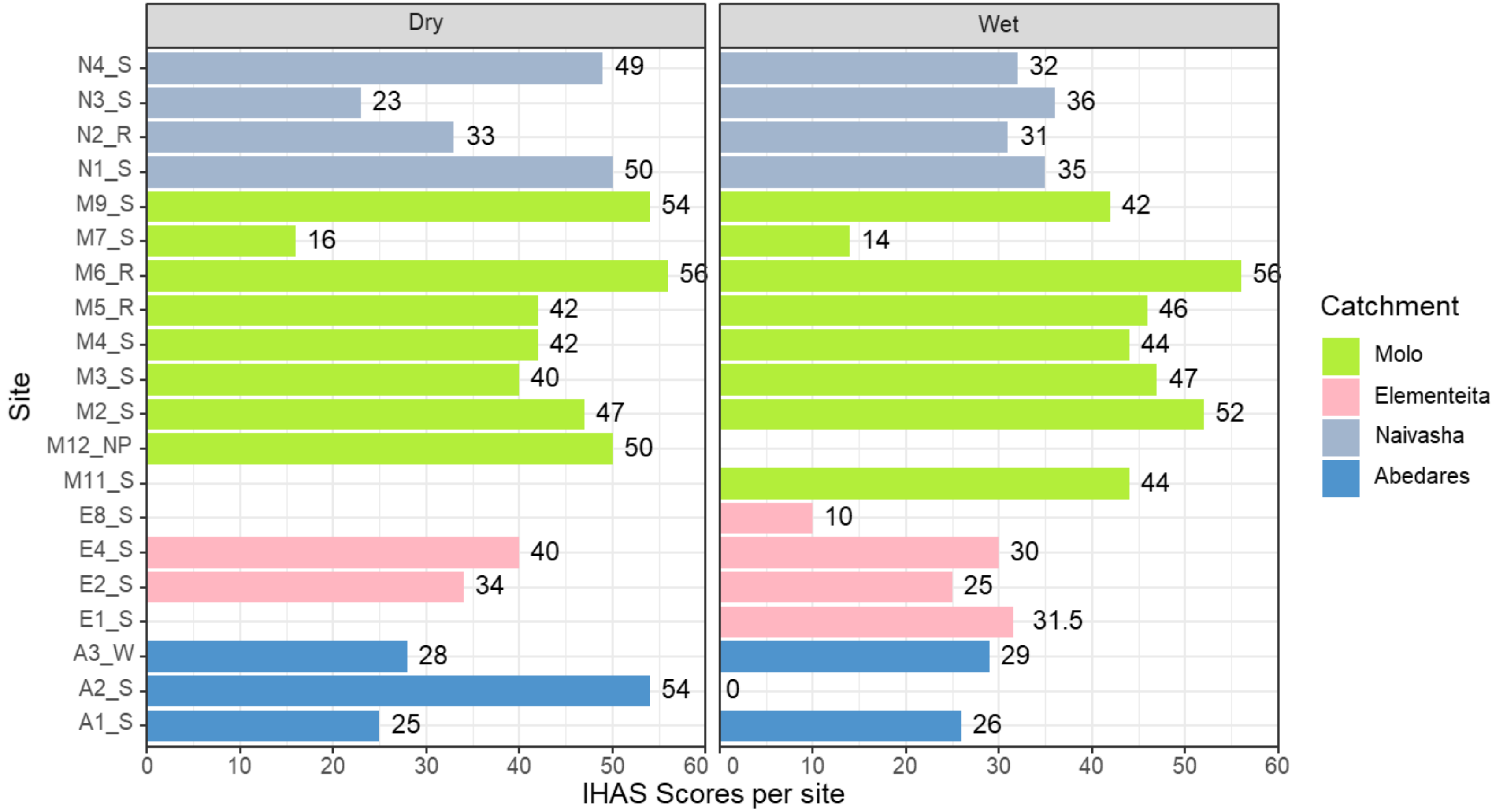

Figure 1: Box plots with average values for macroinvertebrate habitat assessed in the IHAS

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Appendix E – Fish Habitat
Baseline Data
February and April, 2021

Table 1: Fish habitat assessment scores for each site in the Molo catchment in February and April 2021 (Max score = 5)

	Molo											
	M2_S		M3_S		M5_R		M6_R		M9_S		M11_S	M12_NP
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Apr-21
Cover												
Filamentous algae	0.7	0.9									1.3	0.9
Macrophytes												1.4
Emergent aquatic vegetation	1.1	1.7			0.6		1.1	1.9	1.7	0.4	0.6	
Submerged stream bank vegetation				0.4		0.6		0.6	1.1			
Overhanging vegetation												1.1
Leaf litter												
Large woody debris					0.4	0.3	1.0			0.6		
Small woody debris	0.4		0.6	0.6	0.6	0.4	1.0	0.4	0.7	0.6		
Undercut banks												
Roodwads	1.4	2.1	3.6	3.6	3.6	2.9	3.6	2.7	2.1	2.1	1.4	
Substrate												
Mud	3.0	3.0	1.0	1.0		2.0			5.0	5.0	4.0	5.0
Sand	4.0	4.0	3.0	3.0	4.0	4.0	3.0	2.0	1.0	2.0	5.0	
Pebble	2.0	2.0	2.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0	1.0	
Gravel	1.0	1.0	2.0	1.0	1.0		1.0	1.0				
Cobble	2.0	3.0	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0	2.0	
Boulder			3.0	3.0	2.0	1.0	1.0	1.0		2.0	1.0	
Bedrock			4.0	5.0	5.0	5.0	5.0	5.0	2.0			
Velocity-Depth												
Fast Deep (FD)							5.0					
Fast Intermediate (FI)	4.0	4.0	5.0	4.0	5.0	3.0	3.0	4.0	3.0		1.0	
Fast Shallow (FS)	2.0	3.0	3.0	3.0	2.0	1.0	2.0	3.0	2.0	1.0	1.0	
Fast Very Shallow (FVS)			1.0	2.0	1.0							
Slow Deep (SD)			2.0	3.0	4.0	5.0	3.0	4.0	4.0	4.0	5.0	5.0
Slow Shallow (SS)	2.0	2.0	1.0	1.0	1.0	2.0	1.0	2.0	3.0	3.0		1.0

	Molo											
	M2_S		M3_S		M5_R		M6_R		M9_S		M11_S	M12_NP
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Apr-21
Slow Very Shallow (SVS)												

Table 2: Fish habitat assessment scores for each site in the Elementeita, Naivasha and Abedare catchments in February and April 2021 (Max score 5)

	Lake Elementeita				Lake Naivasha							Abedares	
	E1_S		E2_S	E8_S	N1_S		N2_R		N3_S	N4_S		A2_S	
	Feb-21	Apr-21	Apr-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21
Cover													
Filamentous algae										1.0	1.1		
Macrophytes												0.6	0.6
Emergent aquatic vegetation	0.6						2.1	2.1		1.0	1.0	1.1	1.1
Submerged stream bank vegetation					1.3	1.1			0.6	0.3		0.4	0.4
Overhanging vegetation		0.4	0.6	1.1									
Leaf litter				0.9		0.4	1.1	1.1					
Large woody debris	1.1	0.6		0.6			0.6	0.6				0.4	0.4
Small woody debris	1.1											1.1	1.1
Undercut banks													
Roodwads	2.1	1.4	1.4	1.4	2.7	2.1			2.1	2.9	2.1	2.1	2.1
Substrate													
Mud		2.0		5.0	2.0	2.0	3.0	1.0	4.0	1.0	1.0	3.0	3.0
Sand	5.0	5.0		5.0	5.0	5.0	5.0	4.0	2.0	1.0	2.0	1.0	1.0
Pebble					2.0	1.0			2.0	2.0	1.0	1.0	1.0
Gravel	2.0				2.0	2.0	2.0	3.0			1.0	1.0	1.0
Cobble		1.0			2.0	1.0			1.0	2.0	2.0	2.0	2.0
Boulder		2.0			1.0	1.0			1.0			2.0	2.0
Bedrock	4.0	3.0							3.0	5.0	5.0	5.0	5.0
Velocity-Depth													

	Lake Elementeita				Lake Naivasha							Abedares	
	E1_S		E2_S	E8_S	N1_S		N2_R		N3_S	N4_S		A2_S	
	Feb-21	Apr-21	Apr-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21
Fast Deep (FD)												3.0	3.0
Fast Intermediate (FI)	2.0				1.0		3.0	5.0		4.0		5.0	5.0
Fast Shallow (FS)	1.0				2.0	1.0		2.0		2.0		2.0	2.0
Fast Very Shallow (FVS)									1.0				
Slow Deep (SD)	4.0	2.0			2.0	1.0	5.0	2.0		3.0	1.0	2.0	2.0
Slow Shallow (SS)	2.0	5.0	3.0	3.0	5.0	5.0	2.0		5.0	1.0	5.0		
Slow Very Shallow (SVS)			5.0	5.0					3.0		1.0		

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Appendix F – Diatom Community
Baseline Data
February and April, 2021

Table 1: Diatom species abundances, dominance and water quality preferences for the sites in February 2021

Taxa	M6_R	M8_NP	M9_S	E1_S	E2_S	E4_S	N1_S	N2_R	A2_S
Achnanthidium sp.	3				33				26
Caloneis lancettula (Schulz) Lange-Bertalot & Witkowski			5		5	4	7		
Cocconeis euglypta Ehrenberg	4	19				4			
Cocconeis placentula Ehrenberg var. placentula	60	26	4	4	102	15	5	101	5
Craticula buderi (Hustedt) Lange-Bertalot	3								12
Craticula minusculoides (Hustedt) Lange-Bertalot	42	30	4	22	22		5		
Cyclotella meneghiniana Kützing								4	
Cyclotella species	5				5	14		8	
Diploneis ovalis (Hilse) Cleve				5					
Encyonema minutum (Hilse in Rabh.) D.G. Mann	10		2	12	4	8	5	25	5
Epithemia argus (Ehrenberg) Kützing var.*argus*					4		15		
Epithemia sorex Kützing						8	7		
Cymbella turgidula Grunow 1875 in A.Schmidt & al. var. *turgidula*					4		20		
Fallacia pygmaea (Kützing) Stickle & Mann ssp.*pygmaea* Lange-Bertalot				4					
Fragilaria vaucheriae (Kützing) Petersen	5							5	
Frustulia crassinervia (Breb.) Lange-Bertalot et Krammer			5	4					20
Gomphonema rhombicum M. Schmidt	46	20	5	30	36		4	30	
Gomphonema parvulum var.*parvulius* Lange-Bertalot & Reichardt	35	10		30		4			65
Gomphonema species	35		30	30	26		15	33	60
Gyrosigma acuminatum (Kützing)Rabenhorst								14	
Halamphora coffeaeformis (Agardh) Levkov	4	5	5						
Hantzschia amphioxys (Ehr.) Grunow in Cleve et Grunow 1880			4					4	
Hippodonta capitata (Ehr.)Lange-Bert.Metzeltin & Witkowski					8				
Navicula cryptotenella Lange-Bertalot									8

Taxa	M6_R	M8_NP	M9_S	E1_S	E2_S	E4_S	N1_S	N2_R	A2_S
Navicula erifuga Lange-Bertalot		4	14	35	5		5	5	
Navicula radiosa Kützing		3							20
Navicula rostellata Kützing	55	20	45	26			32	33	10
Navicula sp.		20	35	15		10	15	28	5
Navicula symmetrica Patrick				5			5		6
Navicula viridula (Kützing) Ehrenberg			5						
Nitzschia dissipata(Kützing)Grunow var.*dissipata*	4			12					
Nitzschia amphibia Grunow f.*amphibia*	10	40	40	33	26		36		
Nitzschia draveillensis Coste & Ricard									
Nitzschia intermedia Hantzsch ex Cleve & Grunow		20	30	22	15	62	55		
Nitzschia nana Grunow in Van Heurck									
Nitzschia palea (Kützing) W.Smith	3			12			22		5
Nitzschia sp.1	10	15	20	26	26	22	40		
Pinnularia borealis Ehrenberg var. *borealis*				4		15			
Pinnularia subgibba Krammer var. *subgibba*		3					4		
Placoneis clementioides (Hustedt) Cox	3					5			
Planothidium frequentissimum(Lange-Bertalot)Lange-Bertalot									8
Reimeria uniseriata Sala Guerrero & Ferrario								4	43
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot					15		8	5	
Rhopalodia gibba (Ehr.) O.Muller var.*gibba*								8	
Sellaphora pupula (Kützing) Mereschkowksy				30		26	22		8
Sellaphora species	7				4	70	10		
Surirella amphioxys W.Smith				15			13		8
Surirella angusta Kützing	4								
Surirella brebissonii Krammer & Lange-Bertalot var.*brebissonii*						30			

Taxa	M6_R	M8_NP	M9_S	E1_S	E2_S	E4_S	N1_S	N2_R	A2_S
Tryblionella calida (grunow in Cl. & Grun.) D.G. Mann						22			
Tryblionella hungarica (Grunow) D.G. Mann				5		4			
Ulnaria acus (Kützing) Aboal	2								
Ulnaria ulna (Nitzsch.) Compère				22	10				36
Total	**350**	**235**	**253**	**403**	**350**	**323**	**350**	**307**	**350**
Nutrients									
Organics									
Salinity									
Other dominant									
Insufficient cell counts									

Table 2: Diatom species abundances, dominance and water quality preferences for the sites in April 2021

Taxa	M3_S	M6_R	M9_S	M10_W	M11_S	E1_S	E4_S	E8_S	N1_S	N2_R	R2_S	A1_S	A2_S	A5_W
Achnanthes coarctata (Brebisson) Grunow in Cl. & Grun.						4								
Achnanthidium sp.													35	
Anomoeoneis sphaerophora (Ehr.) Pfitzer							25							
Caloneis fontinalis (Grun.) Lange-Bertalot & Reichardt							4							
Caloneis lancettula (Schulz) Lange-Bertalot & Witkowski							26		5	60			5	
Cocconeis placentula Ehrenberg var. *placentula*	35	95	5		10		14	15	15	80	40		10	
Cocconeis species													4	
Craticula minusculoides (Hustedt) Lange-Bertalot	15	45						12						
Cyclotella meneghiniana Kützing							20			25				
Cymbella turgidula Grunow 1875 in A.Schmidt & al. var. *turgidula*			5										5	
Diadesmis confervacea Kützing var. *confervacea*										4				
Diploneis ovalis (Hilse) Cleve							10					15		
Ellerbeckia arenaria (Moore) Crawford							20							
Encyonema minutum (Hilse in Rabh.) D.G. Mann		22				10	4		22	15			4	11
Epithemia argus (Ehrenberg) Kützing var.*argus*							5							
Epithemia sorex Kützing										4		5	4	
Eunotia bilunaris (Ehr.) Mills var. *bilunaris*														4
Eunotia minor (Kützing) Grunow in Van Heurck											4	12		5
Eunotia pectinalis (Dyllwyn) Rabenhorst var.*pectinalis*						4					4			

Taxa	M3_S	M6_R	M9_S	M10_W	M11_S	E1_S	E4_S	E8_S	N1_S	N2_R	R2_S	A1_S	A2_S	A5_W
Fallacia pygmaea (Kützing) Stickle & Mann ssp.pygmaea Lange-Bertalot	15							58						
Fragilaria capucina Desm. v.*capucina* morphotyp 1 Van de Vijver & al.														10
Fragilaria tenera (W.Smith) Lange-Bertalot														22
Fragilaria vaucheriae (Kützing) Petersen		4												
Frustulia crassinervia (Breb.) Lange-Bertalot et Krammer					4				5	5		5	4	
Gomphonema minutum(Ag.)Agardh f. minutum	5		18			20			5	15				
Gomphonema parvulum var.*parvulius* Lange-Bertalot & Reichardt	10	30	10		10	35	4		4	10	25	5	97	
Gomphonema rhombicum M. Schmidt	5	26	35		20	26		40	20		15			4
Gomphonema species	10				10	30			5	4		20	33	66
Gomphonema vibrio Ehrenberg	5											10		
Gyrosigma acuminatum (Kützing)Rabenhorst						4				4				
Hantzschia amphioxys (Ehr.) Grunow in Cleve et Grunow 1880			5											
Hippodonta capitata (Ehr.)Lange-Bert.Metzeltin & Witkowski										15				
Lemnicola hungarica (Grunow) Round & Basson		5	5											
Navicula cryptotenella Lange-Bertalot		5								5				
Navicula erifuga Lange-Bertalot	10		15		25			5	16	5				10
Navicula radiosa Kützing	5		5										5	
Navicula rostellata Kützing	45	15	45		10					35	12		5	
Navicula sp.	5	32	10		5	26	5	38	5	20	18	20	22	44
Navicula viridula (Kützing) Ehrenberg								4		4			4	
Nitzschia amphibia Grunow f.*amphibia*	15	33	30		18	60	35	75	40					

Taxa	M3_S	M6_R	M9_S	M10_W	M11_S	E1_S	E4_S	E8_S	N1_S	N2_R	R2_S	A1_S	A2_S	A5_W
Nitzschia draveillensis Coste & Ricard														
Nitzschia intermedia Hantzsch ex Cleve & Grunow	15		60		50	80	66	60	55	5	15	10		20
Nitzschia palea (Kützing) W.Smith		15	10		10				4		4			
Nitzschia sp.1		30	18		25	15	20	26	25			4	4	5
Pinnularia borealis Ehrenberg var. *borealis*					10	15	10		10			5	5	15
Pinnularia subgibba Krammer var. *subgibba*			26		5	10		10				22	4	11
Pinnularia viridis (Nitzsch) Ehrenberg var.viridis morphotype 1													10	
Placoneis clementioides (Hustedt) Cox										18				
Planothidium frequentissimum(Lange-Bertalot)Lange-Bertalot	5												10	
Reimeria uniseriata Sala Guerrero & Ferrario										5			12	
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot		4												
Rhopalodia gibba (Ehr.) O.Muller var.*gibba*										5				
Sellaphora species													5	
Sellaphora pupula (Kützing) Mereschkowksy	10		18				65	45	25	4				
Staurosira construens Ehrenberg										4				11
Surirella amphioxys W.Smith									4	10			4	
Surirella angusta Kützing					10					22				
Surirella brebissonii Krammer & Lange-Bertalot var.*brebissonii*							75							
Surirella subsalsa W.Smith					6		10							
Tryblionella calida (grunow in Cl. & Grun.) D.G. Mann			10				30	4	5					
Tryblionella hungarica (Grunow) D.G. Mann			10				10							
Ulnaria acus (Kützing) Aboal														10

Taxa	M3_S	M6_R	M9_S	M10_W	M11_S	E1_S	E4_S	E8_S	N1_S	N2_R	R2_S	A1_S	A2_S	A5_W
Ulnaria ulna (Nitzsch.) Compère		14			18	10			4	15		30	88	75
Total	**210**	**375**	**340**	**0**	**246**	**349**	**458**	**392**	**274**	**398**	**137**	**163**	**379**	**323**
Nutrients														
Organics														
Salinity														
Other dominant														
Insufficient cell counts														

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Appendix G – Macroinvertebrate Community Baseline Data
February and April, 2021

Table 1: Macroinvertebrate estimated abundances for the sites in February 2021

Families	M2	M3	M4	M5	M6	M7	M9	E1	E2	E4	N1	N2	N4	A1	A2	A3
Turbellaria	B	A	A	A	A		A		B	A				B	B	A
Oligochaeta	B	A		A	A					A	A		A			
Leeches			A													
Potamonautidae*		1		1												
Atyidae					1											
Perlidae					A		B								A	
Baetidae 1sp						1					A					A
Baetidae 2 sp	C		B									B	B		A	
Baetidae > 2 sp		C		B	C		B	B	B							
Caenidae	B	C	B	C	B		B	A	B	A	A	A	C	B	B	A
Ephemeridae																
Heptageniidae	A	B	1	B	B		B	B	B		A					
Leptophlebiidae		B		A	B		B		B		A					
Polymitarcyidae												A				
Tricorythidae					A		B									
Chlorolestidae				1											A	
Coenagrionidae	A		A	A	B	A	A	A	A				A	A	B	A
Platycnemidae					A											
Aeshnidae					1				A							A
Corduliidae		A											A			
Gomphidae		1							B		A	A			A	
Libellulidae		A			A										A	
Belostomatidae*												A				
Corixidae*	A	A	A	A			A	A		B	A		A		A	A
Gerridae*		A	B	A	A		A	A	A	A	B	A	A			
Hydrometridae*					1					A						
Nepidae*	A															
Notonectidae*			A							A		1	B			
Pleidae*										A						
Veliidae/M...veliidae*			A	A	A	A	A	B	A	A	A		A	A	A	
Ecnomidae				1			A									A

Families	M2	M3	M4	M5	M6	M7	M9	E1	E2	E4	N1	N2	N4	A1	A2	A3
Hydropsychidae 1 sp			B	A						A		B			B	
Hydropsychidae 2 sp	B			B			B		B		C					
Hydropsychidae > 2 sp		C			B											
Hydroptilidae	A	A	A		C		A	B	A		B			A	A	
Lepidostomatidae												A				
Leptoceridae					A											
Dytiscidae*	A			A			A		A	B			B	A		A
Elmidae/Dryopidae*		A		A	A		A				A					
Gyrinidae*	A	A	A	A	A				A		1		B	B		B
Hydrophilidae*				A						B					A	
Athericidae					A											
Ceratopogonidae		1	A	A	A	1		1	A	A						
Chironomidae	B	A	B	B	B	A	A	B	B	B	C	A	B	B	B	A
Culicidae*				A					A	A			A			
Dixidae*														B	A	
Ephydridae						1										
Simuliidae	A	A		B			A			A	B		B	B	C	A
Tipulidae							A		A		A				A	
Ancylidae							A						A	A		
Lymnaeidae*							A									
Physidae*							A									1
Planorbinae*													B			A
Corbiculidae		A														
Sphaeriidae	A			1										A		
Sass score	**71**	**121**	**73**	**129**	**169**	**23**	**138**	**61**	**106**	**63**	**89**	**55**	**68**	**60**	**94**	**59**
No. of taxa	**15**	**20**	**15**	**24**	**24**	**6**	**22**	**10**	**18**	**16**	**16**	**10**	**16**	**12**	**17**	**13**
ASPT	**4.73**	**6.05**	**4.87**	**5.38**	**7.04**	**3.83**	**6.27**	**6.10**	**5.89**	**3.94**	**5.56**	**5.5**	**4.25**	**5**	**5.53**	**4.54**

Molo River	1 = 1 Individual
Lake Elementeita	**A**= 2- 10 individuals
Lake Naivasha	**B**= 11-100 individuals
Abedares	**C**= 101 - 1000 individuals

Families	M2	M3	M4	M5	M6	M7	M9	E1	E2	E4	N1	N2	N4	A1	A2	A3
		D= > 1000 individuals														

Table 2: Macroinvertebrate estimated abundances for the sites in April 2021

Families	M2	M3	M4	M5	M6	M7	M9	M11	E1	E2	E4	E8	N1	N2	N4	A1	A2	A3
Turbellaria	A	A	A	A	A		A	A		A	A					A	A	A
Oligochaeta	A			1	A	1					A			A			A	
Leeches	A		A		A			A							A	A		A
Potamonautidae*								1		1						A	A	
Hydracarina								A							A			
Perlidae					A		A										A	
Baetidae 1sp				A		A			A		A					A		
Baetidae 2 sp			A							A			A	A	A		A	
Baetidae > 2 sp	A	A		A	A		A	A									A	
Caenidae	A	A	A	A	A			A		A				A	A	A		A
Ephemeridae							A											
Heptageniidae	A	A	A	A	A		A	A		A				A				
Leptophlebiidae		A		A			A	A		A				1				
Chlorolestidae			A	A														
Coenagrionidae	A	A	A	A	A	A	A	A	A	A	A			A	A	A	A	A
Aeshnidae		A	A		A													
Corduliidae																	A	
Gomphidae								A		A			A	A			A	
Libellulidae		A						1			A						A	
Belostomatidae*					1									A				
Corixidae*		A	A	A	A		A	A	A		A	A	A	A	A		A	
Gerridae*		A					A	A		A	A	A	A	A	A	1		
Hydrometridae*								1										
Nepidae*	A						1		1									1

Families	M2	M3	M4	M5	M6	M7	M9	M11	E1	E2	E4	E8	N1	N2	N4	A1	A2	A3
Notonectidae*		A		A	A			A	A		A				A		1	
Pleidae*							A					1		A	A			
Veliidae/M...veliidae*		A	A		A	A		A	A	A		A	A	A	A	A	A	A
Hydropsychidae 1 sp			A					A		A								
Hydropsychidae 2 sp	A	A					A						A	A			A	
Hydropsychidae > 2 sp				A	A													
Hydroptilidae		A			A			A		1								
Leptoceridae	A															A	A	
Dytiscidae*			A	A			A	A			A				A	A	A	
Elmidae/Dryopidae*		1		A			1	A										
Gyrinidae*	A	A	A	A	A		A	A			A				A	A		A
Helodidae/Scirtidae																	A	
Hydrophilidae*				A	1													
Athericidae					A													
Ceratopogonidae		A		A				A		1	A		A				A	
Chironomidae	A	A	A	A	A	A	A	A	A	A	d	A	A		A	A	A	A
Culicidae*		A	A	A		1	A	1		1	A		A	1	A	A	A	
Dixidae*								1								1	A	
Muscidae																	A	
Simuliidae	A		A	A	A			A		A	A		A	A		A	A	A
Tipulidae	A			A	A								A			A		
Ancylidae															A			
Bulininae*															A			
Lymnaeidae*			A					1										
Physidae*	A																	

Families	M2	M3	M4	M5	M6	M7	M9	M11	E1	E2	E4	E8	N1	N2	N4	A1	A2	A3
Planorbinae*	A		A									A			A			A
Sphaeriidae			A									A						
Sass score	**80**	**108**	**90**	**119**	**126**	**17**	**110**	**147**	**24**	**83**	**50**	**25**	**49**	**77**	**72**	**72**	**123**	**39**
No. of taxa	**16**	**19**	**19**	**21**	**21**	**6**	**17**	**27**	**7**	**16**	**14**	**7**	**11**	**15**	**17**	**16**	**23**	**10**
ASPT	**5.00**	**5.68**	**4.74**	**5.67**	**6**	**2.83**	**6.47**	**5.44**	**3.43**	**5.19**	**3.57**	**3.57**	**4.45**	**5.13**	**4.24**	**4.5**	**5.35**	**3.90**

Molo River	1 = 1 Individual
Lake Elementeita	**A**= 2- 10 individuals
Lake Naivasha	**B**= 11-100 individuals
Abedares	**C**= 101 - 1000 individuals
	D= > 1000 individuals

Table 3: Macroinvertebrate index scores for sites in February 2021

Sample	No. Families	Evenness	Shannon Diversity	SASS score	No. of taxa	ASPT	%EPT
M2_S	15	0.67	1.81	71	15	4.73	33%
M3_S	20	0.58	1.73	121	20	6.05	30%
M4_S	15	0.80	2.17	73	15	4.87	33%
M5_R	24	0.64	2.03	129	24	5.38	25%
M6_R	24	0.66	2.09	169	24	7.04	38%
M7_S	6	0.86	1.55	23	6	3.83	17%
M9_S	22	0.84	2.58	138	22	6.27	36%
E1_S	10	0.82	1.89	61	10	6.10	40%
E2_S	18	0.86	2.48	106	18	5.89	33%
E4_S	16	0.80	2.22	63	16	3.94	13%
N1_S	16	0.59	1.64	89	16	5.56	38%
N2_R	10	0.73	1.67	55	10	5.50	50%
N4_S	16	0.73	2.04	68	16	4.25	13%
A1_S	12	0.85	2.12	60	12	5.00	17%
A2_S	17	0.67	1.89	94	17	5.53	29%
A3_W	13	0.80	2.04	59	13	4.54	15%

Molo River
Lake Elementeita
Lake Naivasha
Abedares

Table 4: Macroinvertebrate index scores for sites in April2021

Sample	No. Families	Evenness	Shannon Diversity	SASS score	No. of taxa	ASPT	%EPT
M2_S	16	0.791	2.193	80	16	5.00	31%
M3_S	19	0.6866	2.022	108	19	5.68	32%
M4_S	19	0.8534	2.513	90	19	4.74	21%
M5_R	21	0.6567	1.999	119	21	5.67	29%
M6_R	21	0.6488	1.975	126	21	6.00	29%
M7_S	6	0.9086	1.628	17	6	2.83	17%
M9_S	17	0.8076	2.288	110	17	6.47	35%
M11_S	27	0.7803	2.572	147	27	5.44	22%
E1_S	7	0.6851	1.333	24	7	3.43	14%
E2_S	16	0.7328	2.032	83	16	5.19	38%
E4_S	14	0.2829	0.7466	50	14	3.57	7%
E8_NP	7	0.9643	1.876	25	7	3.57	0%
N1_S	11	0.5157	1.237	49	11	4.45	18%
N2_R	15	0.8011	2.169	77	15	5.13	33%
N4_S	17	0.8617	2.441	72	17	4.24	12%
A1_S	16	0.7699	2.135	72	16	4.50	19%
A2_S	23	0.8482	2.66	123	23	5.35	22%
A3_W	10	0.7253	1.67	39	10	3.90	10%
Molo River							
Lake Elementeita							
Lake Naivasha							
Abedares							

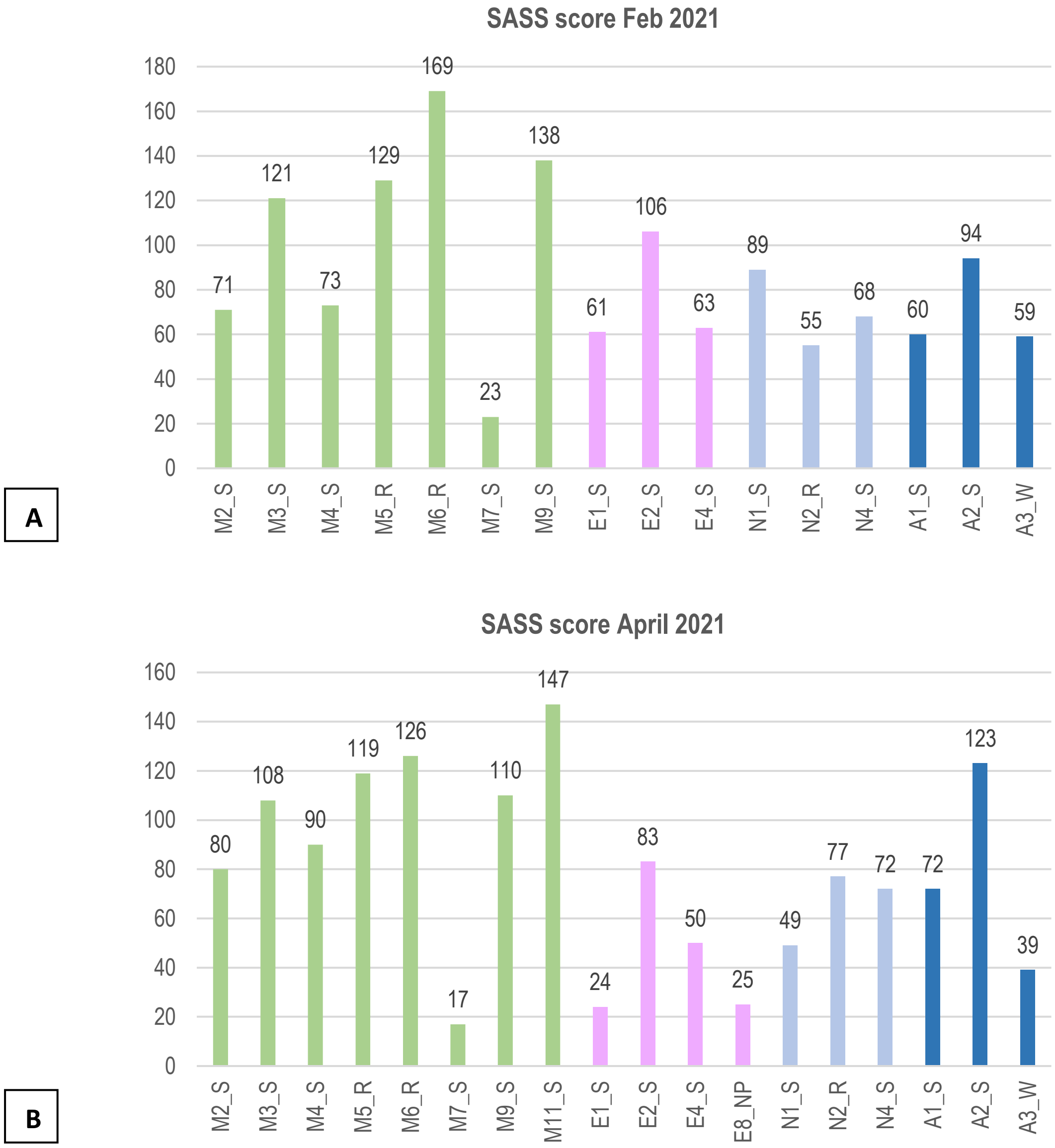
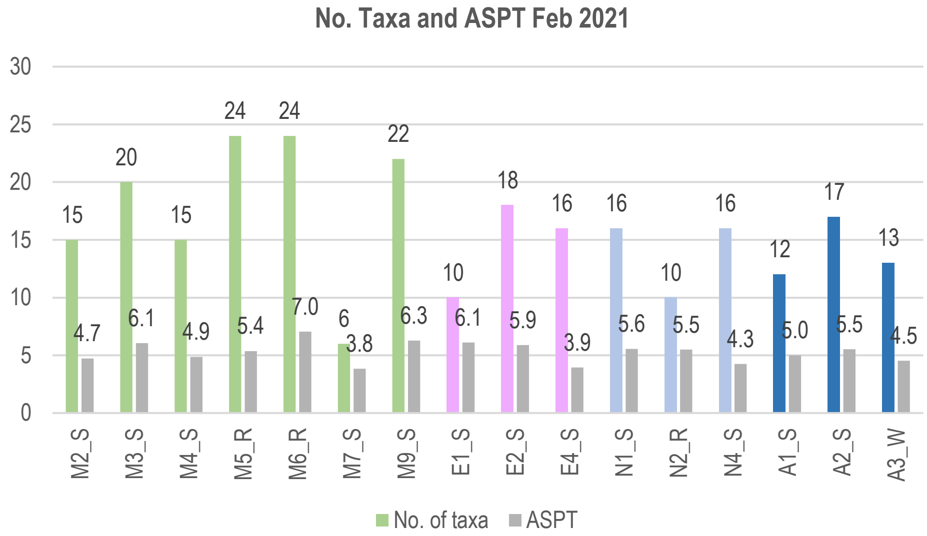


Figure 1: Macroinvertebrate SASS scores per site for (A) February 2021 and (B) April 2021 surveys

A



B

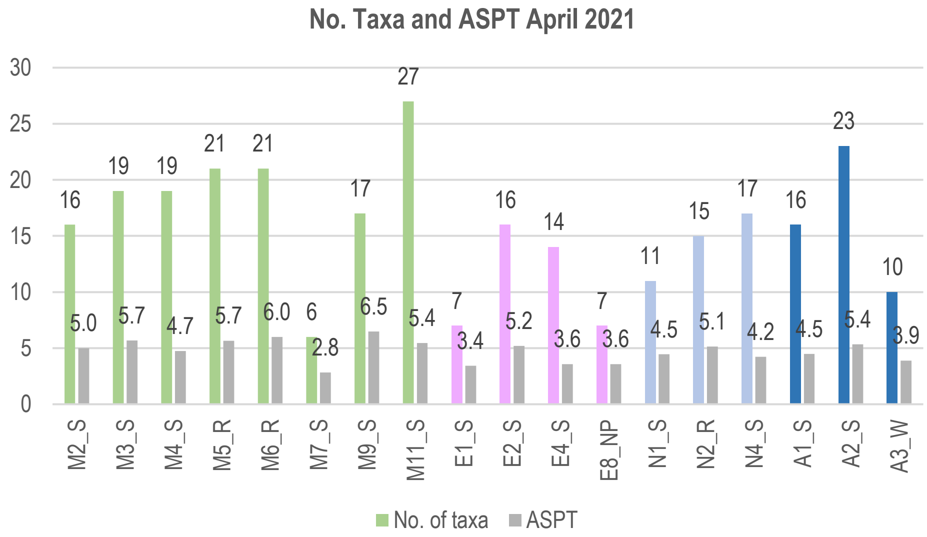


Figure 2: Macroinvertebrate number of families (No. Taxa) and Average Score Per Taxon (ASPT) per site for (A) February 2021 and (B) April 2021 surveys

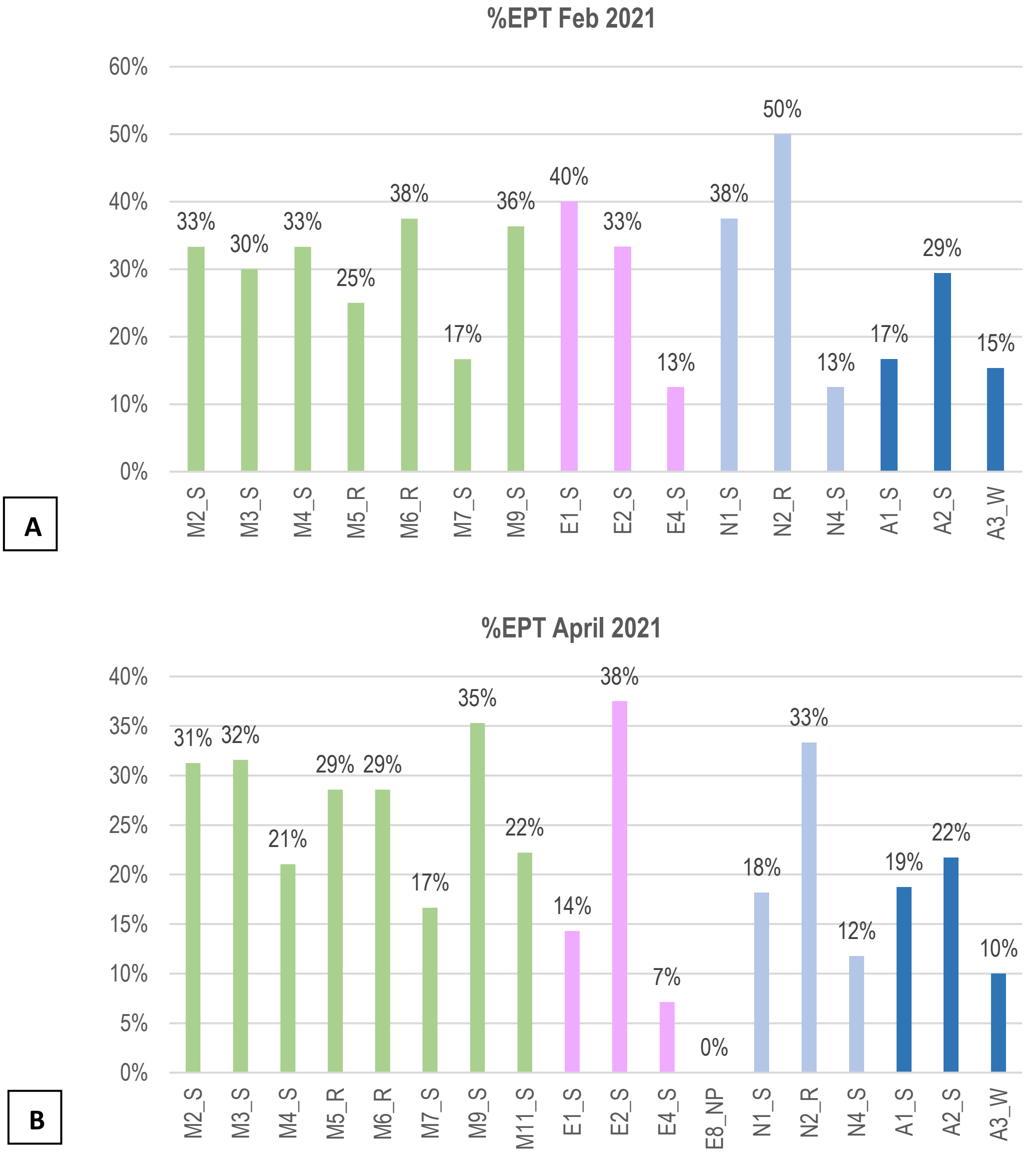


Figure 3: Macroinvertebrate Ephemroptera, Plecoptera and Trichoptera (%EPT) scores for (A) February 2021 and (B) April 2021 surveys

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

Appendix H – Fish Community
Baseline Data
February and April, 2021

Table 1: Fish abundances for sites sampled in the February and April 2021 study

	M2_S	M2_S	M3_S	M3_S	M5_R	M5_R	M6_R	M6_R	M9_S	M9_S	M11_S	M12_NP	E1_S	E1_S	E2_S	E8_S	N1_S	N1_S	N2_R	N2_R	N3_S	N4_S	N4_S	A2_S	A2_S
	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Apr-21	Feb-21	Apr-21	Apr-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21	Apr-21	Feb-21	Apr-21	Feb-21	Apr-21
SILURIFORMES																									
Clariidae (2)																									
Clarias gariepinus								4				1	5	20					1	2					
Clarias cf. werneri							1													1					
CYPRINIFORMES																									
Cyprinidae (4)																									
Cyprinus carpio																				3					
Enteromius kerstenii																			9	21					
Enteromius neumayeri							214	396	1	45															
Enteromius paludinosus									2	9			7	54			18	9	24	58					
CYPRINODONTIFORM																									
Poeciliidae (2)																									
Gambusia affinis									7	8															
Poecilia reticulata									26	75															
PERCIFORMES																									
Cichlidae (2)																									
Pseudocrenilabrus philander												1													
Pseudocrenilabrus multicolor ssp. victoriae																			6	4					
SALMONIFORMES																									
Salmonidae (1)																									
Oncorhynchus mykiss																								12	19
Molo River																									
Lake Elementeita																									
Lake Naivasha																									
Abedares																									

APPENDIX

6-22 *STANDARDISED BIODIVERSITY SENSITIVITY ANALYSIS*

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

STANDARDISED BIODIVERSITY SENSITIVITY ANALYSIS
FINAL REPORT

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July 2021

Document history

Version	Reviewer	Requests noted if any
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Draft V2	WSP – Maya Brennan Jacot	
FINAL	Jérôme Gaugris, *PriSciNat*. Karsten Drescher, *PriSciNat*. Ben Orban, *PriSciNat.* Gina Walsh, *PriSciNat* Lukas Niemand, *PriSciNat* Marius Burger, *PriSciNat* Phoebe Mottram*, CandSciNat* Alain Thomas	

REPUBLIC OF KENYA
STANDARDISED BIODIVERSITY SENSITIVITY ANALYSIS

Contents

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 Rironi-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:

- Standardised biodiversity sensitivity analysis

For this scope of work, FFMES was requested to develop a map of the sensitivity with respect to biodiversity for the landscape of concern for the Kenya project. The scope of the work is performed by asking the team of specialist used for the baseline work to evaluate a range of small-scale datasets, each with a number of summarised variables, on a scale of 1 (very low sensitivity) to 5 (very high sensitivity). This is then combined to represent a spatial overview of the sensitivity as ranked by specialists following the same approach and consideration of the same variables, hence providing a standardised overview on the parameters that drive biodiversity presence in the study area.

2. INTRODUCTION

Sensitivity analyses are typically used to spatially represent the potential conflict zones between humans and biodiversity (Schumacher et al. 2001). These analyses are typically run when isolated data sets need to be collated and when inferences need to be made from limited amounts of information. This is especially the case when large scale study areas (such as the landscape scale considered in the case of the Rironi to Mau Summit Highway Expansion and Upgrade Project) need to be evaluated and where it is impossible to have a detailed and exhaustive sampling in each biodiversity discipline (such as birds, mammals, invertebrates etc.), but where "representative" sampling is required (Bourgeron et al. 2001) and has been conducted to enable adequately robust inferences to be made for areas of comparatively similar potential (Schumacher et al. 2001).

The present approach seeks to integrate the work and perception regarding a range of lifeforms investigated by each specialist through providing a standardised framework of landform and geographical features for the study area within which they have been requested to classify sensitivity in a similar manner, in relation to their field of work. Each specialist has to interpret each variable in the framework and rank it on a scale of one to five in terms of the sensitivity / response of the organisms under consideration to the variable specified.

These analyses provide a powerful framework to analyse and spatially represent data in a more objective manner by "forcing" specialists to consider the same list of variables (including a range that they would not necessarily consider on their own) and establish sensitivity in relation to the variable, although it may not be a straightforward element that would have been normally considered (Cowling et al. 2003; Schumacher et al. 2001).

3. RELEVANT STUDY AREA

The Extended Local Assessment Area identified for the biodiversity aspects of the Project covers 1,378,329 ha and spans almost 200 km from Nairobi to Mau Summit, encompassing the cities of Nakuru and Naivasha. As the land use and land use change data was available for this area as well as the vegation layers (through VECEA project –

see Van Breugel et al. 2015), this Extended Local Assessment Area was retained as a starting point for the Land Use and Land Use Change Analysis (LULUCA). This analysis covered the entire Extended Local Assessment Area and provided a coarse landscape overview, which was then summarised in smaller more relevant sections.

As the sensitivity analysis needs to be applied to a more local level, the following scales were then used to provide a contextual overview:

- Local Assessment Area – flora and fauna – 2 km buffer.
  - This buffer is used to demarcate the zone where direct impact as a result of the project is likely to affect the local level biodiversity (Van der Ree, 2015)
- Extended Local Assessment Area – 10 km buffer
  - A 10 km buffer was used in this study as the Extended Local Assessment Area because it is deemed to better provide an overview of the context that may be affected by direct impacts by association with the project development (increased traffic to the project area and increased use of immediate neighbouring zones). This 10 km buffer is used as it represents the initial two distance classes established in the LULUCA where >50% of the human influence is found.

The outline of the study area, where the present analysis is performed is represented in Figure 1 at a fine grain resolution of 1 ha while the coarse 1 km² resolution summary is presented in Figure 2.

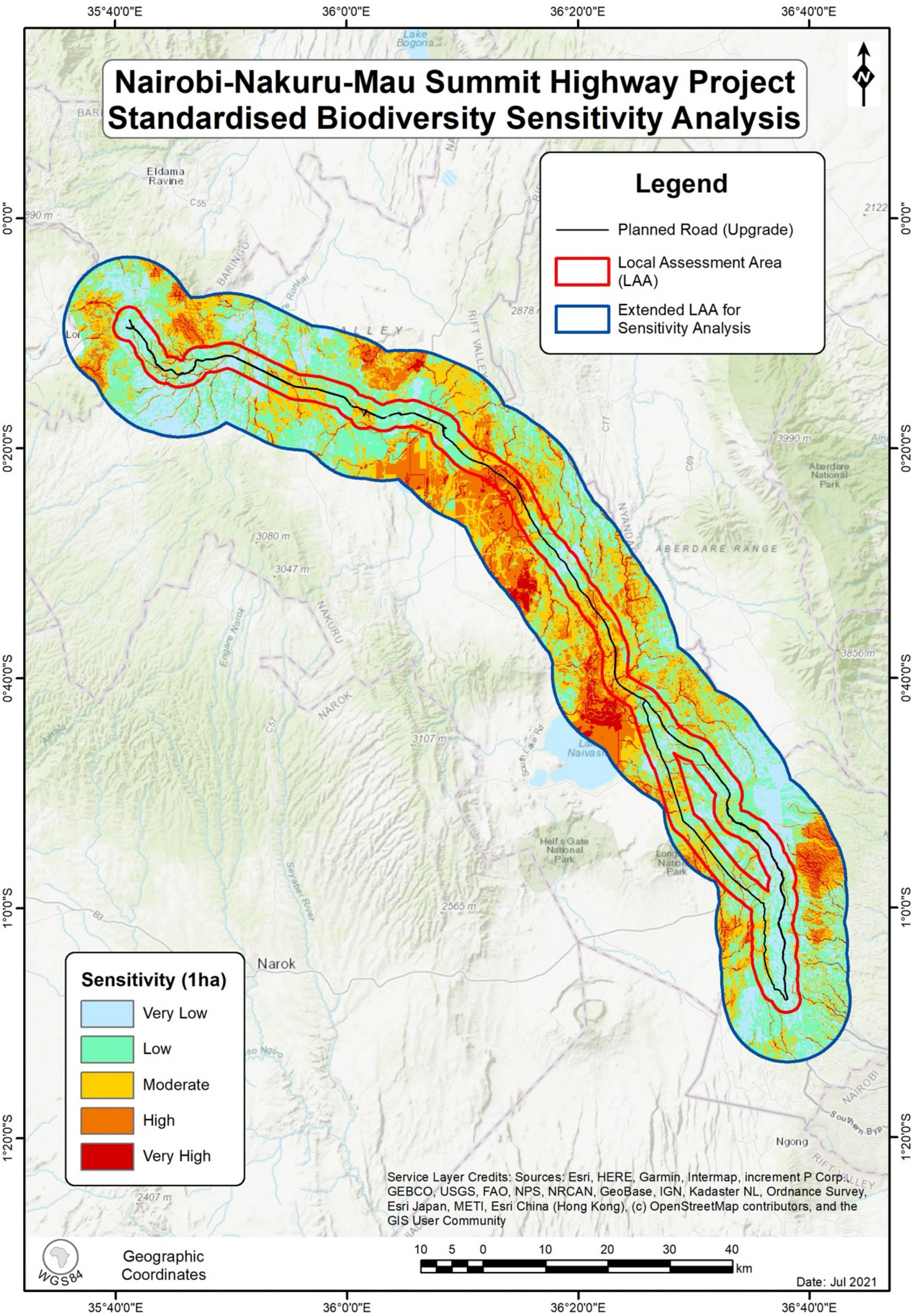

Figure 1: The specific Extended Local Assessment Area considered for the sensitivity analysis, with the sensitivity analysis results already presented at fine scale resolution using 1 ha sized pixels.

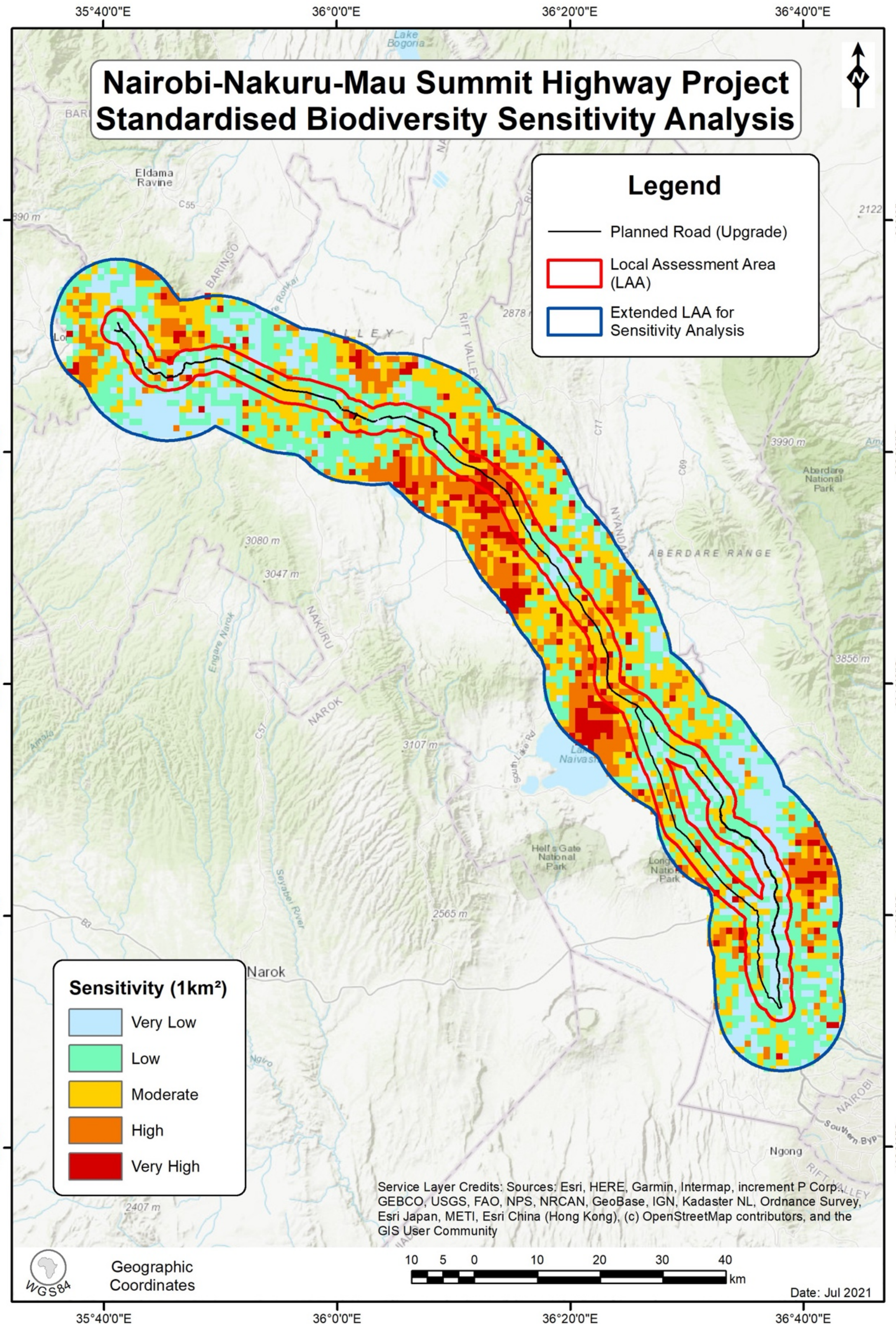

Figure 2: The specific Extended Local Assessment Area considered for the sensitivity analysis, with the sensitivity analysis results already presented at fine scale resolution using 1 km^2 sized pixels.

4. METHODS – SENSITIVITY MODEL PRESENTATION

The aim of this model-based representation of what is termed biodiversity sensitivity is to guide understanding of how biodiversity lifeforms respond to natural or man-made features of the landscape, which can also be considered/interpreted as how important are such features in terms of the way they support/hinder various biodiversity lifeforms in their biological life cycle. From this overview, it thus becomes possible to indicate which single landscape feature, or group of features, are particularly important in terms of their capacity to host/support biodiversity lifeforms and how does biodiversity selectively respond to the presence of such features. This can be represented spatially to illustrate where biodiversity sensitive sites lie within the region of concern.

This approach involves searching for available small scale data sets representing recognisable landscape features, each with a range of situations (called variables), in the landscape of concern, and which can be used for spatial representation in a Geographic Information System (GIS). The range of situations for all identified features of the landscape can then be evaluated in an identical manner by a group of specialists in their respective fields and for specific biodiversity lifeforms that relate to their field of expertise. The question they need to answer for each item is how does the “feature” presented to them relate to the life form they investigated and how “sensitive” is the life form to the item, or in some instances how sensitive is the presence of the item for the sustained presence and survival of the life form, with consideration to the lifecycle of the life form. In the present analysis, the search for small scale datasets was undertaken using freely available sources of information typically found online in the GIS databases. A total of 12 small scale datasets were identified and analysed, while one of these was used to run two separate analyses.

For all instances, the biodiversity lifeforms investigated through the baseline work (plants, birds, mammals, reptiles, amphibians, fish) were evaluated on the basis of their life cycle. The lifecycle aspects were used as the response of a lifeform to a habitat type, or a feature may vary during the various stages of its lifecycle and may as a result modulate the end score in relation to a variable. The following aspects of the life cycle were evaluated when pertinent (Silvy, 2012):

- Feeding habitat: where the food is obtained and where it has the best quality for the long-term survival of the lifeform considered,
- Breeding habitat: where the act of reproduction is best conducted (i.e. where necessary displays of fitness are most likely to result in the act and where the chances of encounters with consorts are optimal,
- Nesting habitat: where the young are brought to life and reared to adulthood in the most optimal manner (avoidance of predation and maximised chances of reaching adulthood)
- Resting habitat: where a species can find the best chances of spending rest periods through minimised predation and optimal shelter from the environment.

For this project, ESRI’s ArcView version 10.1 was used to develop the model. The following 13 small scale datasets (or features) were used, representing a total of 104 Variables to evaluate by each specialist:

1. Vegetation A – 19 variables – VECEA vegetation layers used to evaluate the response to biodiversity lifeforms to the assumed naturally occurring vegetation types. A total of 19 useful variables were relevant for the study area as a whole (however, these were reduced to 15 variables for the two areas of interest summarised). This group of variables represented coarse grain consideration of the vegetation and presence of plant species as it is influenced by orientation, terrain and the underlying geology and soils, but also how the vegetation through availability of cover and fodder may influence the presence of the other lifeforms (Sutherland, 2006; Morrison et al. 2008).
2. Vegetation B – 19 variables – The above layers were re-used with a specific consideration of the suitability with respect to IUCN listed species in terms of their life cycle phases. While this investigation is in some way a repeat of the above coarse grain overview, it was here specifically concerned by the way the vegetation and land cover layer influences endangered lifeforms to use the landscape at various stages of their lifecycle (Sutherland, 2006; Morrison et al. 2008) with a view to focus the evaluation on possible key habitat types that would have been missed through the “broader approach” of the Vegetation A overview. This evaluation was performed with specific reference to the IUCN listed species of concern

identified by TBC (TBC, 2018). The lifecycle phases evaluation of each of the land cover classes was undertaken for two plants, three mammals, four birds, two terrestrial invertebrates, one amphibians, two reptile, two fish and one freshwater invertebrate species. The species are listed below:

IUCN status	Lifeform	*Genus and species*	Encountered in Feb/Apr 2021
EN	Plant	*Lagarosiphon hydrilloides*	No
EN	Plant	*Ethulia scheffleri*	No
EN	Mammal	*Giraffa camelopardalis camelopardalis*	Yes
na	Mammal	*Sylvisorex granti*	No
EN	Mammal	*Redunca fulvorufula*	No
EN	Bird	*Balearica regulorum*	Yes
EN	Bird	*Ardeola idae*	No
EN	Bird	*Macronyx sharpei*	No
VU	Bird	*Cisticola aberdare*	No
EN	Invertebrate	*Notogomphus maathaiae*	No
EN	Invertebrate	*Platycypha amboniensis*	No
VU	Amphibian	*Mertensophryne lonnbergi*	Yes
na	Reptile	*Trioceros jacksonii*	Yes
na	Reptile	*Bitis worthingtoni*	Yes
VU	Invertebrate (freshwater)	*Bulinus permembranaceus*	Uncertain
CR	Fish	*Aplocheilichthys sp. nov. 'Baringo'*	No
CR	Fish	*Labeo victorianus*	No

3. Vegetation C – 12 variables – Land use layers – LULUCA based layers that highlight the level of naturalness of the landscape were used. This group of variables represented coarse grain consideration of the land use practices in the landscape and presence of humans in a broad manner, especially how, through their presence the human aspects have shaped the landscape and availability of cover and fodder that may influence the presence of the wild lifeforms (Sutherland, 2006; Morrison et al. 2008).
4. Distance to villages / settlements – 6 variables, representing six classes of distance to such human features and asking the experts how each distance class may influence the lifeform they investigated. The six classes represent an output of an analysis summarising all the distance to nearest human settlement, pixel by pixel and reclassified within an easier to interpret group of six broad increasing distance classes away from the human settlement places. The villages and settlements data set was extracted from LULUCA body of work and from the open source database of roads and towns. This feature was considered important to gauge how the biodiversity lifeforms respond to permanent or near permanent human presence and noise, as well as the associated disturbance effect that may be linked to it (Sutherland, 2006; Morrison et al. 2008).
5. Distance to roads or tracks developed by humans – 5 variables. Similar representation and request as per distance to villages or settlements above. As mobile biodiversity lifeforms may be negatively affected by human presence in the landscape, the presence of roads and tracks, promoting human presence may be a concern and was considered as an important element to consider and rank. This also applies to sessile biodiversity lifeforms, as humans will initially select plants nearest to access roads or paths for harvesting (Sutherland, 2006; Morrison et al. 2008).
6. Distance to rivers or streams or waterlines – 5 variables, as per the distance to villages / settlements above, five classes of distance to the nearest water line (whether a temporary or permanent water system) were defined and the experts were requested to express how this may influence the presence of biodiversity lifeforms. As water availability is a highly sensitive item for the presence of most biodiversity lifeforms in the landscape, this feature was considered important (Sutherland, 2006; Morrison et al. 2008).
7. Altitudinal classes – 8 variables were defined (altitude range from 990 to 3,983 m altitude) for the greater landscape and used for assessment. Altitudinal positioning in the landscape may promote the development of local microclimate or conditions of higher endemism, which in turn may be increasingly

sensitive to any changes, whether directly related to human presence/use or indirectly (local climate change as a result of dust for example) (Sutherland, 2006; Morrison et al. 2008);

8. Slope (analysis in degrees from 0 - >20 degrees) – 5 variables (0 – 5°, 5 – 10°, 10 – 15°, 15 – 20°, >20°). Slope is a factor of direct use or direct avoidance by a range of lifeforms and can be represented as a refuge habitat in some instances when humans are typically excluded through slope, the variable was therefore considered as important to evaluate (Sutherland, 2006; Morrison et al. 2008),
9. Aspect – 5 variables (Flat, North, East, South, West). The general orientation of each pixel in the landscape was defined into these five variable values. The orientation of the landscape in relation to the sun may have an influence on vegetation types and associated use of the vegetation by wildlife. This was considered useful to assess (Sutherland, 2006; Morrison et al. 2008).
10. Wetness Index (based on SAGA GIS software[1]) – 5 variables. This feature represents a combined analysis of soil moisture (very low to very high) and soil texture (very coarse texture to very fine texture). This is considered an important variable that will dictate the presence of plant species groups and the associated presence of wildlife depending on its affinities for the associated plants and correlated moisture and texture levels (Sutherland, 2006; Morrison et al. 2008).
11. Water Lines – 5 variables to illustrate the length of individual streams or water line before they merge with another and the associated successive increases in size until they form the larger river systems for the landscape. The presence of water is a key parameter for freshwater ecology, but may also dictate the presence and nature of all other lifeforms depending on their level of dependency. Moreover water lines, depending on their size, may create opportunistic habitat or barriers, and may represent a key parameter for mobile or sessile biodiversity species presence (or absence). This was considered important to identify and assess (Sutherland, 2006; Morrison et al. 2008).
12. Topographical ruggedness (based on SAGA GIS software) – 5 variables. Ruggedness is defined through a further analysis of soil texture and slope, and represents the likely combined presence of topographical level cavities, crevasses and "chaotic nature" formations promoted by increasingly complex associations of slope and ground texture, this is represented through five increasing variables in a way that makes the terrain increasingly complex to cross and use. This feature is an important element of availability of refuge for seeds and many wildlife species at numerous parts of their lifecycle (Sutherland, 2006; Morrison et al. 2008).
13. Landform (Topographic Position Index Analysis) derived from the Shuttle Radar Topography Mission (SRTM) – 10 variables. Each pixel of the study area was tested for its "landform position". The landform types in a landscape will be typified by presence of different groups of lifeforms, or separate use of landform types for different parts of their lifecycle. This was considered a key criterion to assess (Sutherland, 2006; Morrison et al. 2008).

All the above GIS small scale datasets layers, whether vector based (shapes) or raster (images) based, were standardised to 100 m (1 ha) pixel raster layers. The variables contained in these various small scale datasets raster layers were summarised in a spread sheet format to enable the various specialists involved to evaluate the features contained in the raster layers in relation to their field of expertise (fauna, flora and aquatic species).

Each of the variables of each small-scale dataset were evaluated by the group of experts (Ben Orban – plants, Alain Thomas – Mammals, Gina Walsh – freshwater aspects, Lukas Niemand – Birds and terrestrial Invertebrates, Marius Burger – Herpetofauna) consulted[2] on a scale of one to five, where one represents very low sensitivity in relation to the variable considered and five represents a very high sensitivity in relation to the variable considered. The weighting was assigned by each expert to each of the variables within the small-scale datasets. All small-scale datasets were then re-scaled against a score of 100, to ensure that no dataset had a greater weight than another when analysis takes place. Within a small-scale dataset, all lifecycle rankings were given a mean value.

[1] http://www.saga-gis.org/en/index.html - accessed 2018

[2] The group of experts consulted were the experts that undertook the biodiversity baseline work in February and April 2021

Once this rescaling was done, the small-scale datasets were then combined (summed) to generate a total environmental sensitivity model, which was resampled at 100 m pixel resolution. These were illustrated to highlight sensitivity of the study area biodiversity to the compound range of features and their variables based on a natural scale. A representation at 1 ha scale was used to provide a fine grain overview while a summary at 1 km² using the sampling grid system was developed to better highlight areas of importance in the landscape of concern.

Small scale datasets were then evaluated back to establish which datasets drove sensitivity response and which variables in particular were important to consider as key drivers, with the understanding that such variables will be essential to consider with respect to impact.

5. LIMITATIONS

The model attempts to use coarse scale data (sampling effort scale) and to represent it at a fine scale (100 m pixel size). The model is implemented on a study area that has been adequately sampled and provides a good sampling structure for using interpolation, and while the model allows such inferences to be made and provides a reasonable background for doing so, the model will always remain limited by the validity of the inputs made. At this stage, all inputs are based on educated expert opinion, stemming from a sampling effort considered as "representative" for each discipline and designed to be optimal in terms of timelines available and type of information required. The representativeness of sampling is presented in each of the relevant baseline reports (see species accumulation curves and expert statements provided) and needs to be considered when confronting the results of the model to planned project developments.

6. RESULTS AND DISCUSSION

6.1. General outlook

The small-scale datasets were scored by 5 experts of FFMES. The Local Assessment Area for flora and fauna within the 2 km buffer zone represented 91,022 ha investigated. This area had a generally low sensitivity for biodiversity with 42% of the area classified in that sensitivity class while a further 21% was classified as very low sensitivity. The higher sensitivity classes combined (classes 3, 4 & 5) totalled 37% of the area investigated (Table 1). At a broader level, considering the extended local assessment zone within the 10 km buffer zone (representing 377,955 ha), while the same picture appears (Table 1), there was a generally higher proportion of the landscape falling within the higher sensitivity classes (47%). This highlights that the landscape closer to the road is generally less sensitive than the bigger landscape in consideration here.

Table 1: Summary of the area per sensitivity class per assessment area considered.

Sensitivity class	Local Assessment Area – flora and fauna – 2 km		Extended Local Assessment Area – 10 km buffer	
	Area in ha per sensitivity class	% of total	Area in ha per sensitivity class	% of total
1	18,958	20.8%	64,078	17.0%
2	38,302	42.1%	135,341	35.8%
3	23,029	25.3%	105,626	27.9%
4	8,791	9.7%	58,787	15.6%
5	1,942	2.1%	14,123	3.7%
Total	91,022	100.0%	377,955	100.0%

There are, however, some exceptions. The area within each sensitivity class was summarised for each conservation area (conservation area are listed in Table 2) along the local assessment area within the 2 km buffer zone (Table 2) and highlighted the following:

- Nearly 49% of Nakuru National Park flagged as high sensitivity.
- The other four conservation areas generally had half of their estate flagged as medium sensitivity.

- Generally, the sum of areas classified as sensitivity classes 3, 4 and 5 for the protected areas represented >70% of the conservation areas estate.

Considering that the protected area status (meant to imply the fact that an area is under a form of conservation management, whether public sector such as national parks and reserves or private sector such as conservancies) was not a small-scale dataset evaluated the analysis highlights the relative importance of the protected areas in the landscape of the road development alignment.

Table 2: Summary of area per sensitivity class for the conservation areas and the sections of land flagged as "areas of interest" along the road alignment.

Feature	Name	Area in ha per sensitivity class for the feature and % of total per feature										Total	% of total
		1	% of total per feature	2		3		4		5			
Conservation areas													
1	Nakuru NP	121	0.6%	1,660	8.7%	6,226	32.8%	9,273	48.8%	1,711	9.0%	18,991	34.2%
2	Mbo-I-Kamiti	26	1.4%	463	25.8%	965	53.8%	262	14.6%	78	4.3%	1,794	3.2%
3	Kigio	0	0.0%	232	19.1%	637	52.3%	322	26.5%	26	2.1%	1,217	2.2%
4	Soysambu	12	0.1%	2,145	10.6%	8,369	41.5%	8,301	41.2%	1,326	6.6%	20,153	36.3%
5	Marula	223	1.7%	2,186	16.3%	6,790	50.7%	3,634	27.1%	564	4.2%	13,397	24.1%
	Total	383	0.7%	6,688	12.0%	22,990	41.4%	21,796	39.2%	3,710	6.7%	55,567	
Special areas													
1	Elmentaita dry ridge with euphorbia	0	0.0%	73	45.3%	53	32.9%	34	21.1%	1	0.6%	161	1.1%
2	Escarpment forest zone	729	20.9%	1,554	44.6%	1,023	29.4%	170	4.9%	7	0.2%	3,483	24.5%
3	Kinale Forest Zone	2,727	51.9%	1,583	30.1%	602	11.5%	286	5.4%	59	1.1%	5,257	37.0%
4	Koibatek Forest Natural Habitat zone	231	44.7%	206	39.8%	57	11.0%	12	2.3%	11	2.1%	517	3.6%
5	KWS zone	8	8.9%	33	36.7%	26	28.9%	23	25.6%	0	0.0%	90	0.6%
6	Manguo Pond-Limuru	28	36.8%	38	50.0%	7	9.2%	3	3.9%	0	0.0%	76	0.5%
7	Marula Estates road reserve zone	58	5.8%	253	25.2%	459	45.8%	196	19.5%	37	3.7%	1,003	7.1%
8	Molo forest plantation zone	582	18.5%	1,453	46.2%	734	23.3%	245	7.8%	131	4.2%	3,145	22.1%
9	Soysambu Road reserve zone shape	0	0.0%	0	0.0%	32	9.8%	281	86.2%	13	4.0%	326	2.3%
10	Thika-Mangu flyover grassland zone	0	0.0%	110	76.9%	28	19.6%	5	3.5%	0	0.0%	143	1.0%
	Total	4,363	30.7%	5,303	37.3%	3,021	21.3%	1,255	8.8%	259	1.8%	14,201	

The sections of land along the road flagged as "areas of interest" by TBC (TBC, 2018) were also summarised in the same manner (Table 2). The following was apparent in this case:

- A total of 4 of the 10 special zones had a generally medium to high sensitivity level defined by having most of the surface area classified within sensitivity classes 3, 4 and 5. These are:
  - The Elementaita dry ridge with Euphorbia (not identified by TBC but noted by FFMES during the reconnaissance visit of November 2020) where 54.7% of the land was classified within these sensitivity classes.
  - The Kenya Wildlife Service training institute area.
  - The Marula estates road reserve zone.
  - The Soysambu road reserve zone.
    - In this case 100% of the surface summarised was in the sensitivity classes 3, 4 & 5.
- The remaining 6 special zones had most of their surface within the low to very low sensitivity classes, highlighting a generally degraded nature of these features.

6.2. Analysis of small-scale datasets

The area within each class of sensitivity was calculated for each variable of each small-scale dataset to determine which variables influenced biodiversity presence in the landscape. The summary of this analysis is presented in Table 3 and highlights that the following small-scale datasets were important for sensitivity:

- Vegetation
  - Four of the 15 habitat types flagged as high sensitivity (having the greater portion of their extent in sensitivity class 4):
    - Afromontane rain forest.
    - Water bodies.
    - Riverine wooded vegetation.

    - Edaphic grasslands on drainage-impeded, seasonally flooded soils or freshwater swamp.
- Land use classes:
  - Three of the 12 land use classes evaluated flagged as high sensitivity:
    - Closed woodlands and forests.
    - Water.
    - Wetlands.

Table 3: Summary of results for sensitivity for each variable of the list of 13 small scale datasets used. The vegetation datasets were combined in this analysis

		Area in ha per sensitivity class for the small-scale dataset variable						
Veg_ID	**VECEA_habitat_type_name**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	Afromontane rain forest	7,519	33,326	29,069	55,332	25,339	150,585	10.9%
4	Afromontane undifferentiated forest	89,176	186,109	154,697	113,138	37,769	580,889	42.1%
6	Single-dominant Hagenia abyssinica forest	1,451	3,647	1,940	169	39	7,246	0.5%
10	Afromontane dry transitional forest	9,505	2,089	1,041	249	97	12,981	0.9%
19	Evergreen and semi-evergreen bushland and thicket	15,394	60,769	71,573	43,596	10,978	202,310	14.7%
25	Upland Acacia wooded grassland	10,748	17,056	15,789	8,455	1,773	53,821	3.9%
35	Afroalpine vegetation	41	179	91	4	0	315	0.0%
36	Afromontane bamboo	67,313	53,922	79,594	21,602	4,132	226,563	16.4%
37	Montane Ericaceous belt	1,066	11,317	21,397	3,023	524	37,327	2.7%
43	Halophytic vegetation	53	852	1,459	259	114	2,737	0.2%
45	Edaphic wooded grassland on drainage-impeded or seasonally flooded soils	14,089	29,777	14,877	3,481	1,135	63,359	4.6%
51	Water bodies	5	102	2,788	12,293	1,507	16,695	1.2%
54	Afromontane desert	824	64	2	0	0	890	0.1%
59	Riverine wooded vegetation	163	2,661	5,744	7,276	2,413	18,257	1.3%
247	Edaphic grassland on drainage-impeded, seasonally flooded soils or freshwater swamp	1	177	1,433	2,439	2,212	6,262	0.5%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

LUC_ID	Variable = vegetation / land use class	Area in ha per sensitivity class for the small scale dataset variable 1	2	3	4	5	Total (ha)	Total (%)
1	Villages and towns	7,699	6,582	1,521	379	14	16,195	1.2%
2	Mines and major excavations	133	408	257	72	11	881	0.1%
3	Cultivation and severe deforestation/degradation (with old lands and minor settlements included)	159,360	251,285	141,497	35,089	8,278	595,509	43.2%
4	Permanent cultivation (green houses)	571	1,674	884	133	19	3,281	0.2%
5	Plantations	8,807	11,196	6,390	1,842	344	28,579	2.1%
6	Medium to severe deforestation/degradation and old lands	18,309	26,672	25,134	10,026	2,254	82,395	6.0%
7	Sparse woodlands and grasslands	1,046	10,166	25,384	19,128	5,501	61,225	4.4%
8	Open to dense woodlands	9,434	37,808	77,051	53,003	12,440	189,736	13.8%
9	Degraded closed woodlands and forests	3,997	18,193	31,478	17,775	4,220	75,663	5.5%
10	Closed woodlands and forests	7,695	36,470	86,222	118,419	51,135	299,941	21.8%
11	Water	34	827	5,002	14,171	2,580	22,614	1.6%
12	Wetlands	0	21	354	1,163	1,178	2,716	0.2%
	Total in ha	217,085	401,302	401,174	271,200	87,974	1,378,735	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

DistV_ID	Variable = Distance to villages (m)	Area in ha per sensitivity class for the small scale dataset variable 1	2	3	4	5	Total (ha)	Total (%)
1	0 - 290	3,059	580	142	40	9	3,830	0.3%
2	291 - 4583	182,399	218,424	89,349	29,279	6,850	526,301	38.1%

		1	2	3	4	5	Total (ha)	Total (%)
3	4584 - 8877	27,264	138,838	179,548	121,801	28,093	495,544	35.9%
4	8878 - 13171	3,424	27,786	83,996	79,332	34,310	228,848	16.6%
5	13172 - 17464	730	11,492	36,623	33,479	14,175	96,499	7.0%
6	> 17464	472	4,927	11,836	7,385	4,595	29,215	2.1%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
DistR_ID	**Variable = Distance to roads (m)**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	0 - 157	176,702	234,017	89,907	23,026	4,461	528,113	38.3%
2	158 - 1251	37,506	142,942	197,698	113,445	25,983	517,574	37.5%
3	1252 - 2345	2,855	18,607	57,202	64,815	19,691	163,170	11.8%
4	2346 - 3439	249	4,529	28,591	37,442	16,115	86,926	6.3%
5	> 3439	36	1,952	28,096	32,588	21,782	84,454	6.1%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
DistStr_ID	**Variable = Distance to river of stream (m)**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	0 - 626	59,461	131,513	146,105	115,886	58,692	511,657	37.1%
2	627 - 1539	86,399	146,927	140,334	86,858	17,552	478,070	34.6%
3	1540 - 2453	43,231	72,705	70,184	41,017	6,858	233,995	17.0%

4	2454 - 3366	18,894	35,010	31,116	18,452	3,118	106,590	7.7%
5	> 3366	9,363	15,892	13,755	9,103	1,812	49,925	3.6%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
Alt_ID	**Variable = Altitude range of pixel**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	990 - 1517	144	752	1,169	258	106	2,429	0.2%
2	1518 - 1802	3,133	11,549	21,181	21,384	6,617	63,864	4.6%
3	1803 - 1956	15,595	46,057	51,172	44,181	13,590	170,595	12.4%
4	1957 - 2039	13,087	32,509	31,970	14,384	3,859	95,809	6.9%
5	2040 - 2192	17,069	58,156	51,993	33,797	16,131	177,146	12.8%
6	2193 - 2477	63,613	112,915	106,733	92,842	34,048	410,151	29.7%
7	2478 - 3005	98,765	119,285	104,941	58,009	12,902	393,902	28.5%
8	3006 - 3983	5,942	20,824	32,335	6,461	779	66,341	4.8%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
Slope_ID	**Variable = Slope categories (in degrees = Deg)**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	0 - 5 Deg (Plains)	99,649	226,672	199,283	127,745	44,696	698,045	50.6%
2	5 - 10 Deg (Ridge)	81,378	103,287	107,661	75,981	29,283	397,590	28.8%

3	10 - 15 Deg (Ridge)	24,718	41,286	52,469	38,037	9,646	166,156	12.0%
4	15 - 20 Deg (Ridge)	6,385	16,790	25,137	18,852	3,835	70,999	5.1%
5	20 + Deg (Ridge)	5,218	14,012	16,944	10,701	572	47,447	3.4%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
Aspect_ID	**Variable = General orientation of pixel**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	-1 - 0 (Flat)	15	260	3,186	12,463	1,668	17,592	1.3%
2	0 - 45, 315 - 360 (N)	67,605	96,364	85,130	48,727	11,565	309,391	22.4%
3	45 - 135 (E)	57,207	112,514	107,060	70,550	22,273	369,604	26.8%
4	135 - 225 (S)	35,896	86,343	101,178	74,476	31,832	329,725	23.9%
5	225 - 315 (W)	56,625	106,566	104,940	65,100	20,694	353,925	25.6%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
Class	**Wetness Index Description**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	Terrestrial - Rocky/ wilting point	121,877	154,918	160,567	105,852	18,579	561,793	40.7%
2	Terrestrial - Wilting point/ field capacity	78,011	142,480	109,317	55,697	15,218	400,723	29.0%
3	Transitional - Field capacity/ temporary (seep) wetlands	11,875	63,585	73,045	47,089	16,957	212,551	15.4%
4	Wetland - Temporary/ seasonal wetlands	4,503	32,423	43,441	39,492	24,406	144,265	10.5%

5	Aquatic - Seasonal/ permanent wetlands	1,082	8,641	15,124	23,186	12,872	60,905	4.4%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
Str_ID	**Variable = Stream order**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
0	No Streams	217,334	401,732	397,002	253,114	55,059	1,324,241	95.9%
1	smallest tributary	9	199	2,977	11,897	18,571	33,653	2.4%
2		5	115	1,351	4,726	8,939	15,136	1.1%
3		0	1	130	1,133	3,287	4,551	0.3%
4		0	0	28	390	1,561	1,979	0.1%
5	Largest river	0	0	6	56	615	677	0.0%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
RI	**Variable = Ruggedness**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	Low STD values	59,111	113,058	98,278	57,804	15,410	343,661	24.9%
2		107,559	170,594	146,563	99,704	34,075	558,495	40.5%
3		33,353	71,388	91,561	78,229	32,054	306,585	22.2%
4		13,041	35,456	50,190	29,837	5,672	134,196	9.7%
5	High STD values	4,284	11,551	14,902	5,742	821	37,300	2.7%

		Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
		% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

		Area in ha per sensitivity class for the small scale dataset variable						
Class	**Variable = Landforms (TPI Analysis)**	**1**	**2**	**3**	**4**	**5**	**Total (ha)**	**Total (%)**
1	Canyons / deeply incised streams	1,310	5,876	14,996	20,088	23,681	65,951	4.8%
2	Midslope drainages, shallow valleys	7,057	19,319	30,705	30,954	16,762	104,797	7.6%
3	Upland drainages / headwaters	866	2,673	4,279	2,826	842	11,486	0.8%
4	U-shape valleys	2,579	16,558	28,787	23,855	8,873	80,652	5.8%
5	Plains	76,400	186,412	154,620	91,388	24,062	532,882	38.6%
6	Open slopes	80,303	92,615	81,406	48,575	4,696	307,595	22.3%
7	Upper slopes / mesas	18,306	30,802	29,543	13,231	2,093	93,975	6.8%
8	Local ridges / hills in valleys	209	1,141	2,844	2,114	378	6,686	0.5%
9	Midslope ridges / small hills in plains	18,024	26,507	32,166	24,218	4,769	105,684	7.7%
10	Mountain tops / high ridges	12,294	20,144	22,148	14,067	1,876	70,529	5.1%
	Total in ha	217,348	402,047	401,494	271,316	88,032	1,380,237	100.0%
	% of total	15.7%	29.1%	29.1%	19.7%	6.4%	100.0%	

- Distance to village:
  - None of the variables flagged noticeably although areas of the landscape placed at least 4.6 km away from villages had a trend for medium to high sensitivity.
- Distance to road:
  - Sections of land situated at least 1.3 km away from roads flagged as having high sensitivity.
- Altitude:
  - The sections of land situated between 1,518 and 1,802 m altitude flagged as high sensitivity while other altitudinal ranges were generally medium to low sensitivity. The altitudinal range that appears as high sensitivity represents the transition zone between, the rift valley bottom and the top of the escarpment zone.
- General orientation:
  - Sections of land considered as flat and without specific orientation flagged as high sensitivity. Sections of land oriented to the south flagged as medium sensitivity while other orientations flagged as low sensitivity.
- Wetness index:
  - Sections of land represented by the aquatic domain of seasonal or permanent wetlands flagged as high sensitivity.
- Stream orders:
  - Sections of land with a stream or a river generally flagged as high sensitivity. This highlights the probable role of river systems or streams as corridors of connectivity in the degraded landscape matrix;
- Landforms:
  - Sections of land classified as deeply incised streams or small canyons flagged as very high sensitivity, further emphasizing the role of the river and stream network as passageways for wildlife and representing connectivity corridors.
  - Sections of land classified as Midslope drainages and shallow valleys flagged as high sensitivity, highlighting the importance of the foothills section on either side of the rift valley as perhaps highlighted by the altitude small scale dataset.

The above summary highlights the importance of flat to south facing portions of land containing Forest or woodland systems, Water bodies, Riverine systems, Marshes and wetlands, including seep zones in grasslands, situated away from villages and roads and located between 1,500 and 1,800 m altitude. The presence of streams and drainage lines acting as corridors of connectivity for wildlife is a further feature of importance.

In summary, less important features for study area were:
- Distance to rivers or streams.
- Slope.
- Ruggedness.

7. CONCLUSION

Sensitivity in the present evaluation represents the sensitivity of a life forms to a specified attribute observed in the landscape, whether it be of natural type or of anthropogenic origin. This is evaluated in the study area context.

The standardised sensitivity analysis provides a background of expected sensitivity of the study area, which in this case is aimed broadly at the various lifeforms that compose biodiversity and were investigated during the biodiversity baseline work conducted in February and April 2021.

Generally, in the context of the study area, 12.0% of the local assessment area and 19.3% of the extended local assessment area within 10 km of the road has been considered as habitat of high to very high / extreme sensitivity for the group of life forms considered. This result is relatively low (typical scores for natural areas are situated between 25 – 40%). This must be considered as a significant result for the landscape and highlights a widespread level of degradation that has narrowed down the opportunities for biodiversity lifeforms to thrive. It is clear that conservation areas represent essential strongholds to be protected while some of the "areas of interest" (two of which are within the conservation area network) also represent places of high priority for any conservation-based action. Further consideration needs to be attracted to maintaining connectivity corridors along river / streams systems of the study area, especially if such systems are fringed by remnants of natural vegetation that can be classified as woodland or forest.

For any development of the road alignment, the relevance of a well-designed low impact strategy for development complemented by conservation-oriented actions is key. Indeed, areas classified as having high to very high sensitivity (under such a combined sensitivity representation) are most likely to represent "critical habitat" under the IFC PS6 guidelines and therefore may require an offset-based mitigation strategy should they be impacted significantly (Palomo et al., 2012; Rajvanshi et al., 2010). They may also represent priority areas of interest for offset based mitigation should the need arise after the impact assessment has been conducted.

Future Project infrastructure placement plans should be re-evaluated considering the present analysis combined with an analysis on ecosystem services functionality in order to complete a least cost placement study and search for sites with the most optimal characteristics within the general project development zone. Should engineering parameters be incorporated, it would be possible to simultaneously investigate solutions that would also have an acceptable cost for development in engineering terms.

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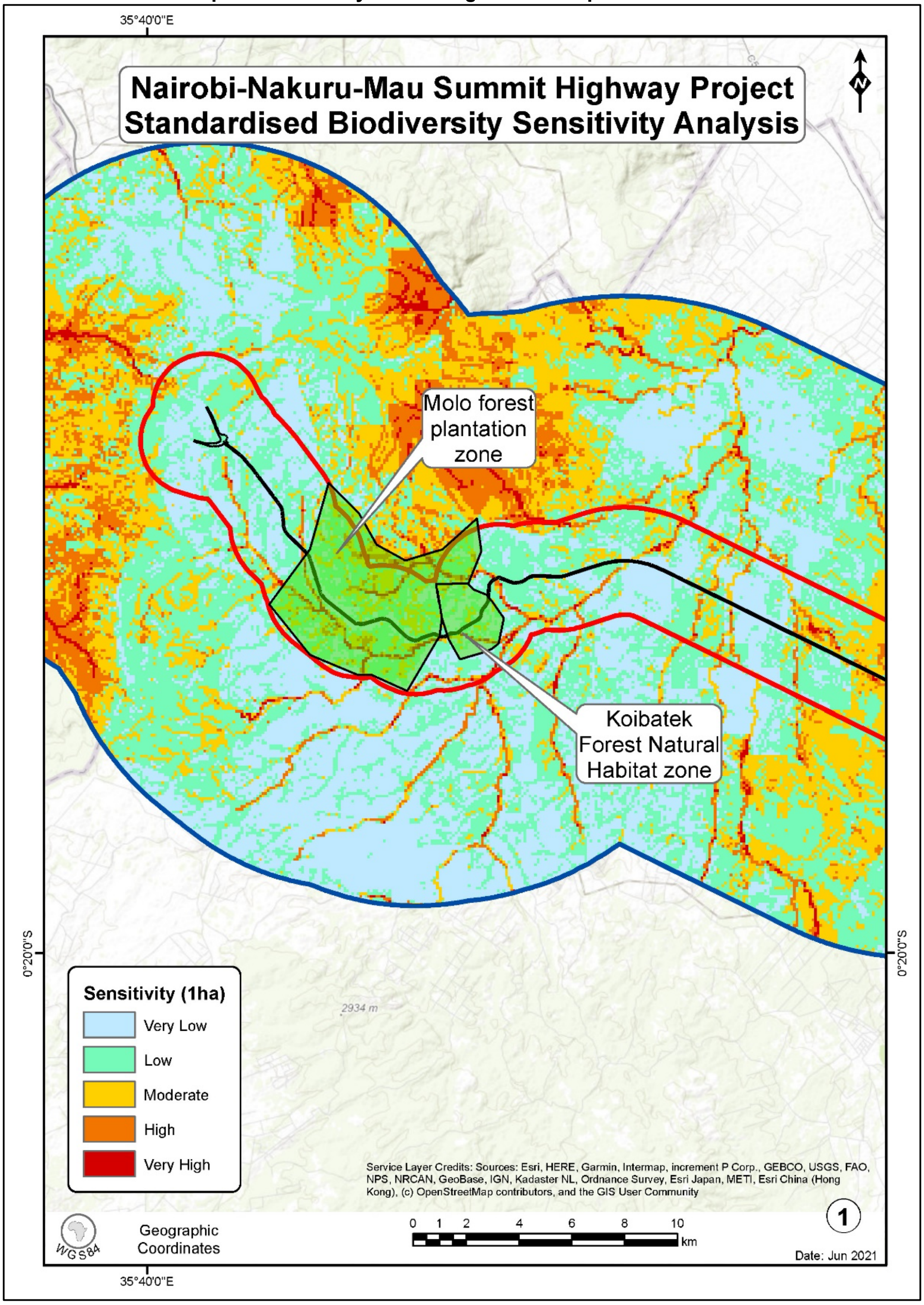
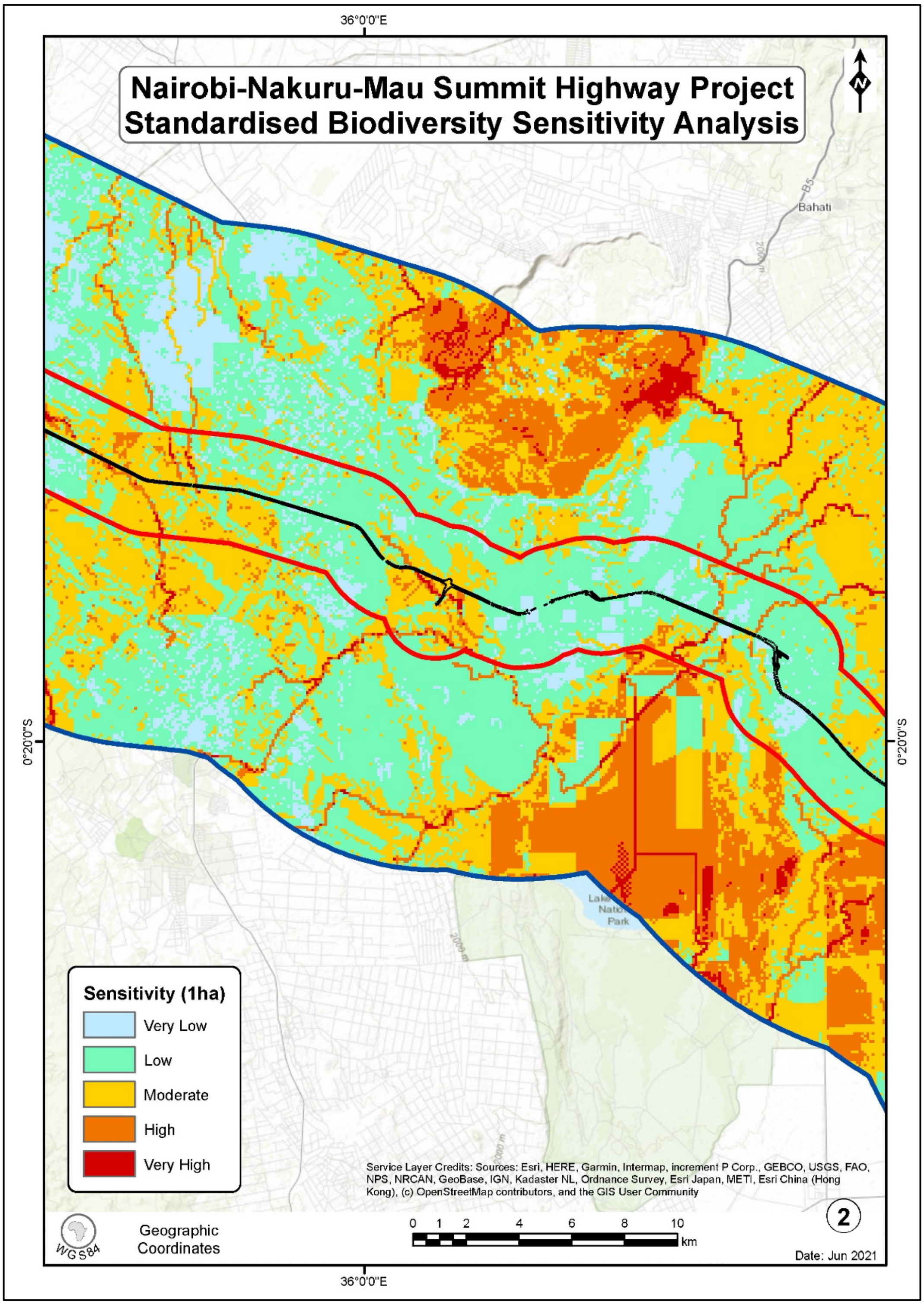
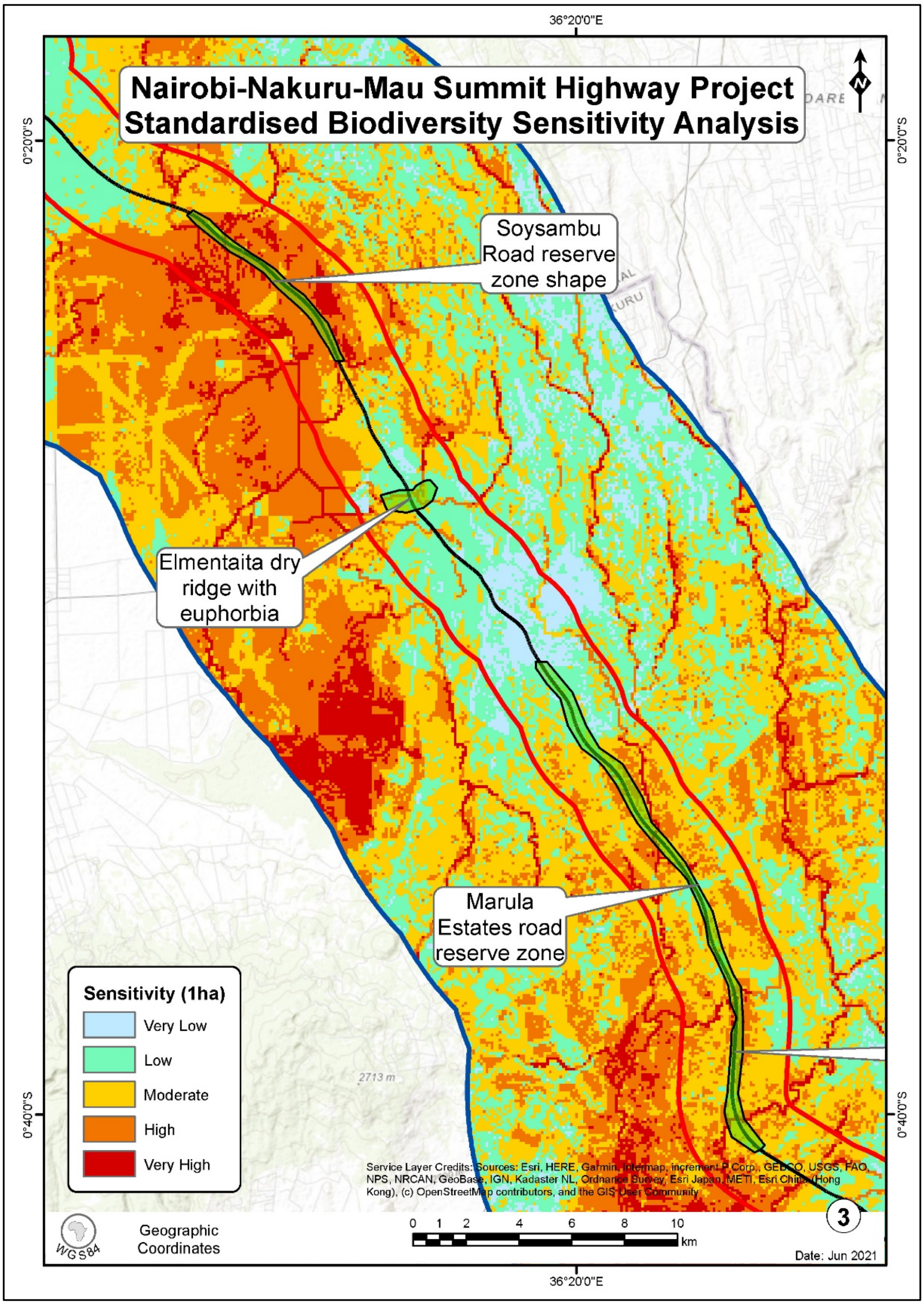
Appendix 1: Portfolio of maps for the study area using the 1 ha representation.




36°0'0"E
Nairobi-Nakuru-Mau Summit Highway Project
Standardised Biodiversity Sensitivity Analysis
N
Bahati
Lake Nakuru National Park
0°20'0"S
Sensitivity (1ha)
Very Low
Low
Moderate
High
Very High
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
2
WGS84
Geographic Coordinates
0 1 2 4 6 8 10 km
Date: Jun 2021


Nairobi-Nakuru-Mau Summit Highway Project
Standardised Biodiversity Sensitivity Analysis
36°20'0"E
0°20'0"S
0°40'0"S
Soysambu Road reserve zone shape
Elmentaita dry ridge with euphorbia
Marula Estates road reserve zone
Sensitivity (1ha)
Very Low
Low
Moderate
High
Very High
2713 m
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
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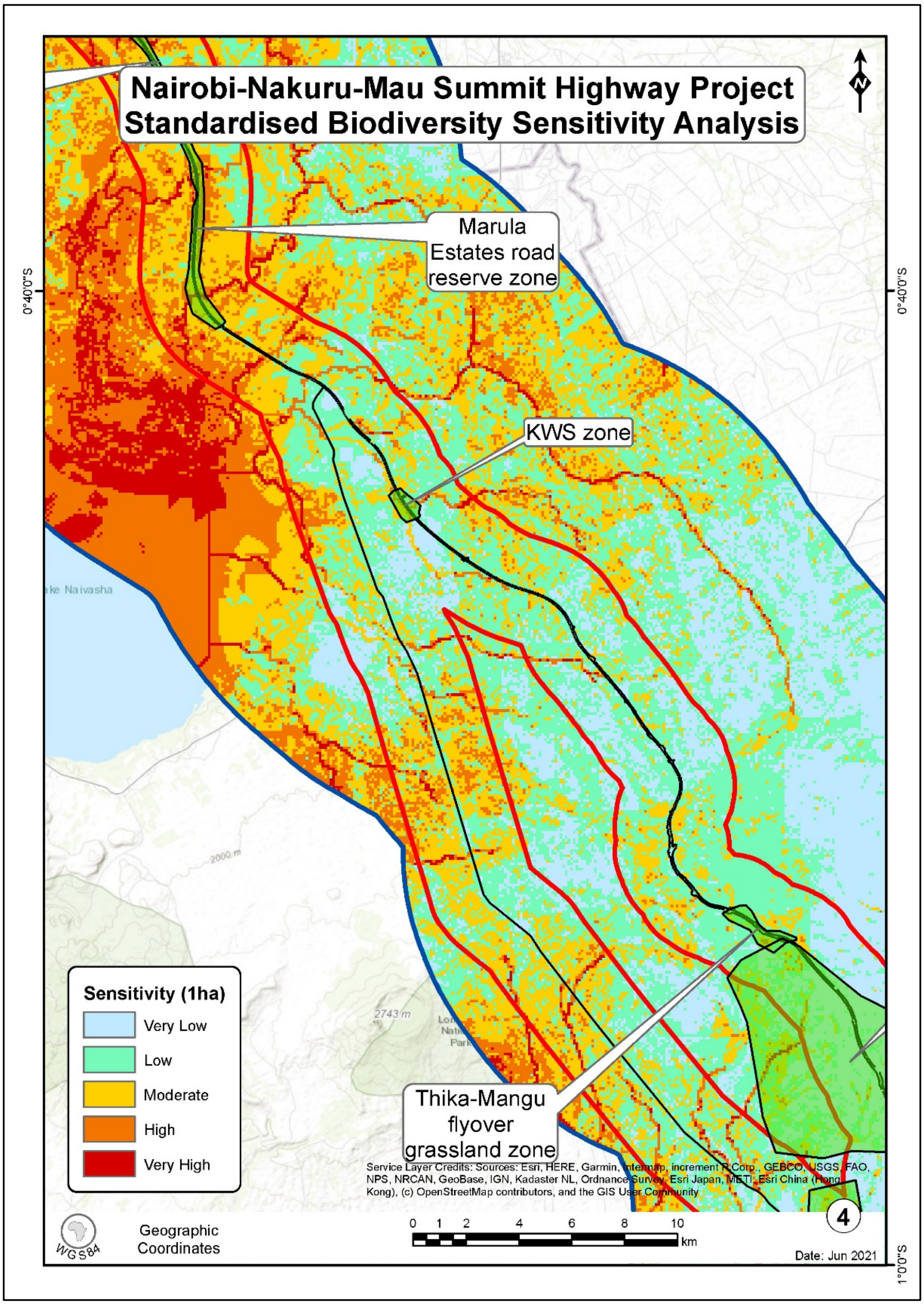
Date: Jun 2021


Nairobi-Nakuru-Mau Summit Highway Project
Standardised Biodiversity Sensitivity Analysis
Marula Estates road reserve zone
KWS zone
Thika-Mangu flyover grassland zone
Lake Naivasha
2000 m
2743 m
0°40'0"S
1°0'0"S
Sensitivity (1ha)
Very Low
Low
Moderate
High
Very High
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WGS84
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0 1 2 4 6 8 10
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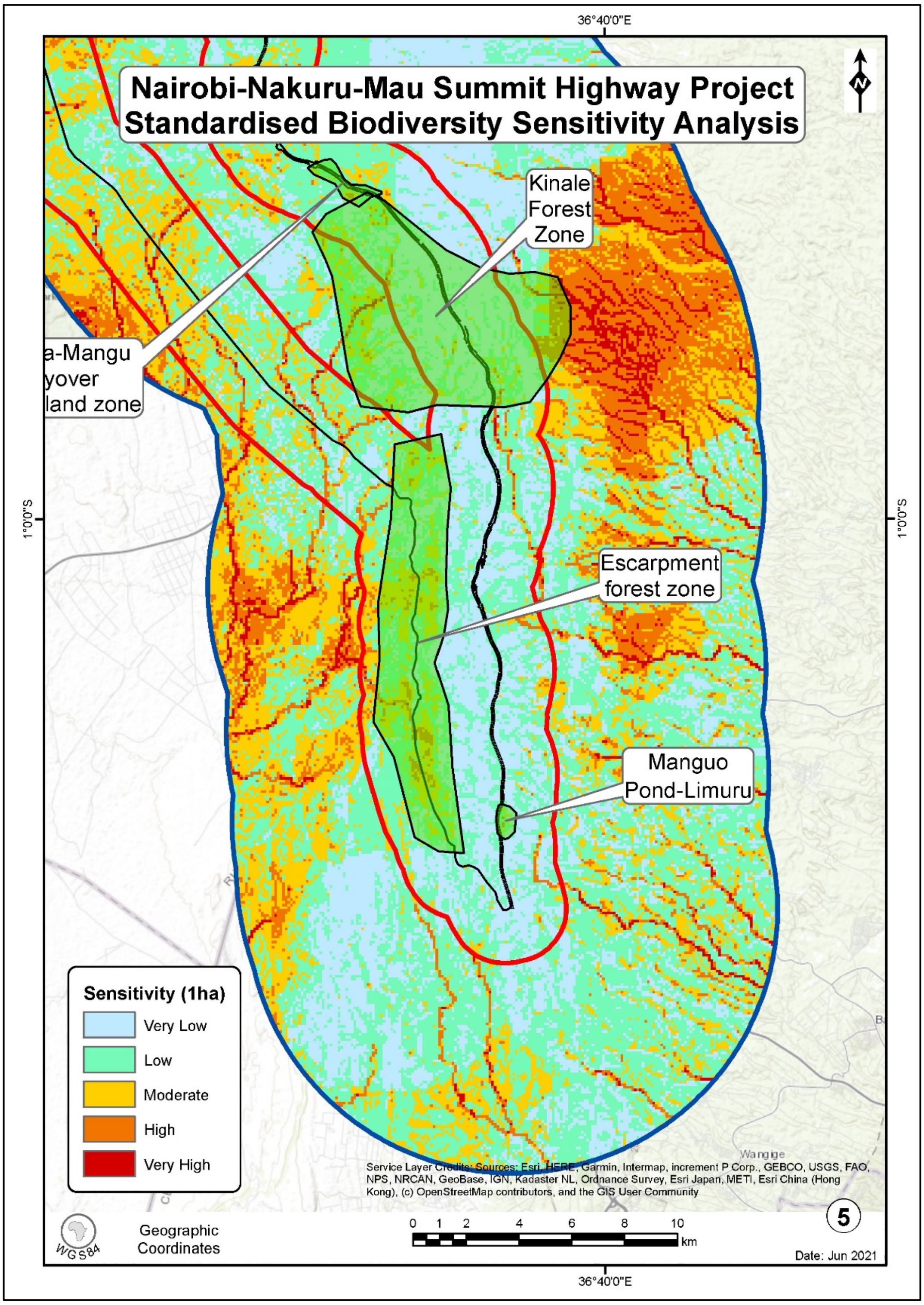
4
Date: Jun 2021


Nairobi-Nakuru-Mau Summit Highway Project
Standardised Biodiversity Sensitivity Analysis
Kinale Forest Zone
a-Mangu yover land zone
Escarpment forest zone
Manguo Pond-Limuru
Sensitivity (1ha)
Very Low
Low
Moderate
High
Very High
36°40'0"E
1°0'0"S
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
WGS84
Geographic Coordinates
0 1 2 4 6 8 10 km
5
Date: Jun 2021

APPENDIX

6-23 *IFC PS6 HABITAT ANALYSIS*

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

IFC PS6 HABITAT ANALYSIS
FINAL REPORT

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Document History

Version	Reviewer	Request
Draft V1	WSP – Maya Brennan Jacot	
FINAL version	Phoebe Mottram, *Cand.Sci.Nat* Jerome Gaugris, *Pri.Sci.Nat.*	

Table of Contents

Nairobi-Nakuru-Mau Summit Highway Project
Expansion & Upgrade
Republic of Kenya

CRITICAL HABITAT ANALYSIS
DRAFT REPORT

1 CONTEXT AND INTRODUCTION

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 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 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,
- International Finance Corporation (IFC) habitat classification according to the Performance Standard 6 (PS6).

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

- IFC habitat classification.

The present evaluation is aimed at defining how the Nairobi-Nakuru-Mau Summit Highway Expansion and Upgrade Project study area will be influenced under the various habitat classes described (modified, natural and critical habitats) in the IFC PS6 (standard of 2012 – referred to as IFC PS6, 2012; Guidance note of 2019 – referred to as IFC PS6, 2019) by representing these classes geographically. The analysis is performed to guide project design and ensure the mitigation hierarchy can be adequately considered and followed. The present report therefore provides a review of the IFC PS6 key elements in relation to the project in order to develop a map of the project area and separate the three IFC PS6 habitat classes spatially.

2 METHODOLOGY

The IFC PS6 standard of 2012 (IFC PS6, 2012) and guidance notes of 2019 (IFC PS6, 2019) were reviewed. Sections of specific relevance to the definition of three habitat classes recognised in the PS6 and required for the project were highlighted and discussed, especially in terms of habitat definition and habitat classification, as well as in terms of species and habitat choices for the purposes of classification. The PS6 Guidance Notes are used to assist with the separation of information.

3 RESULTS

3.1 IFC PS6 Habitat Classification – review

In the review below, original text of the IFC PS6 (2012 or 2019) is represented in *italics brown text*, while our observations appear in normal black text.

3.1.1 Protection and Conservation of Biodiversity

PS6 § 9 (2012 version). Habitat is defined as a terrestrial, freshwater, or marine geographical unit or airway that supports assemblages of living organisms and their interactions with the non-living environment. For the purposes of implementation of this Performance Standard, habitats are divided into modified, natural, and critical. Critical habitats are a subset of modified or natural habitats.

For the purposes of the Nairobi-Nakuru-Mau Summit project study area, the terrestrial and freshwater habitats components are considered.

PS6 § GN13 (2019 version). For some projects, biodiversity values and ecosystem services associated with a site might be numerous, and, in these cases, it is recommended that client undertake a prioritisation of such features. One potential way biodiversity and ecosystem services can be prioritised is along two axes:

- *(i) the number of spatial options left where conservation can occur (i.e., spatial limitation or the feature's irreplaceability); and*
- *(ii) the time available for conservation to occur before the feature is lost (i.e., temporal limitation as caused by threats to the feature in question, which will provide an understanding of its vulnerability) …*

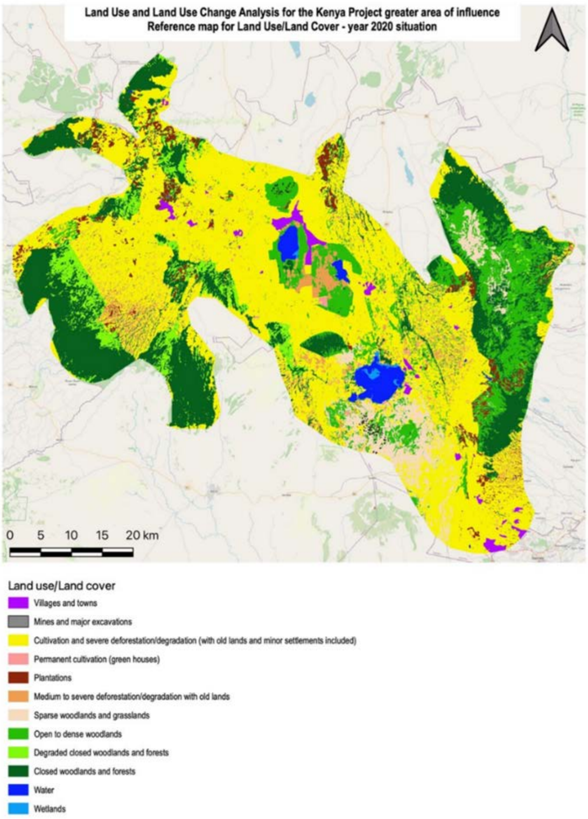
The Nairobi-Nakuru-Mau Summit Highway Expansion and Upgrade Project area is located across a substantial region of Kenya and traverses a range of habitats located at a wide range of altitudinal levels. The highway traverses the Rift Valley in a transversal manner and as a result includes two distinct ecotones between the lowland systems of the rift valleys situated at 1900 m altitude and the Afromontane region situated at 2,500 m altitude, on the western and eastern sides of the rift valley axis respectively.

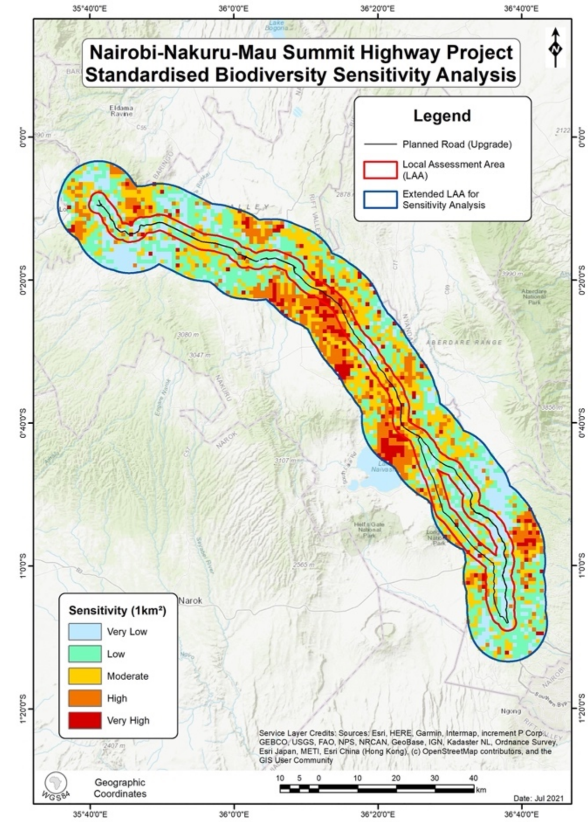
Based on the land use and land use change analysis (LULUCA) done (Mottram and Gaugris, 2021) the greater part of this landscape is degraded and substantial conversion of natural land into agricultural estate has intervened. From the LULUCA, the general outlook is one of a switch from a landscape that was 60% natural in 2000 to one that is 55% under the direct influence of mankind in 2020 with agricultural expansion and plantations representing two major sources of change in the study area. Figure 1a provides a general overview of the 2020 situation.

The standardised biodiversity sensitivity analysis (SBSA) undertaken (Gaugris, 2021) has highlighted that conservation areas (whether privately managed or state owned) represent pockets of biodiversity in a landscape otherwise defined by a low to very low remaining sensitivity. Indeed, 42% of the landscape situated within the local assessment area (LAA) for habitats and flora (2 km on either side of the road alignment) falls within the low sensitivity category of the analysis (on a scale of 1 = very low sensitivity to 5 = very high sensitivity), while +/-36% of the landscape situated 10 km from the road falls in that category. The conservation areas by contrast have the majority of their surface in the medium to high sensitivity classes. The SBSA further highlighted the importance of river systems and riverine vegetation associated as connectivity zones for biodiversity through the landscape. Figure 1b provides an outlook of the situation.

The LULUCA and SBSA results highlight a rapidly changing landscape where the existing conservation area network made of privately managed sectors and state-owned land requires urgent attention to ensure that natural connectivity between the conservation areas and across the road can be maintained. Options are limited in space, and as the rate of change is significant, the options are limited in time as the road may rapidly close several currently existing opportunities.

Maintaining connectivity for biodiversity values and associated ecosystem services and natural resources values along the two ecotonal zones represented by the sections of land linking the rift valley floor to the upland sections represents a further challenge. It is quite possible that a range of species use this altitudinal gradient as a way to adjust to seasonal changes in resources. Therefore, opportunities to conserve connectivity between upland and lowlands need to be considered in addition to connectivity options across the road.





a) LULUCA study results for the Nairobi-Nakuru--Mau Summit Highway Expansion and Upgrade Project, highlighting the 2020 situation after 20 years of change were analysed over a landscape of 1,378,329 ha.	b) SBSA study results highlighting the sensitivity of the landscape of concern within a 10 km buffer zone on either side of the road alignment incorporating the LAA. As can be seen, a substantial portion of the landscape appears in blue (very low to low sensitivity.

Figure 1: Representation of the LULUCA and the SBSA studies results for the landscape of concern

PS6 § GN26 (2019 version). Paragraph 9 of Performance Standard 6 purposely provides a broad definition of habitats as geographical units (that include marine and freshwater aquatic areas as well as airway passages), which is clearly a departure from a classic ecological definition of habitat (i.e., the place or type of site where an organism or population naturally occurs). Modified, natural and critical habitat refers to the biodiversity value of the area as determined by species, ecosystems and ecological processes. As part of the risks and impacts identification process, the client should develop and present a map of the modified, natural, and/or critical habitats in the landscape of the project's area of influence to inform the applicability of Performance Standard 6.

PS6 § GN27 (2019 version). In practice, natural and modified habitats exist on a continuum that ranges from largely untouched, pristine natural habitats to intensively managed modified habitats. In reality, project sites will often be located among a mosaic of habitats with varying levels of anthropogenic and/or natural disturbance. Clients are responsible for delineating the project site as best as possible in terms of modified and natural habitat.

This determination is made based on the level of human-induced disturbance (e.g., presence of invasive species, level of pollution, extent of habitat fragmentation, viability of existing naturally-occurring species assemblages, resemblance of existing ecosystem functionality and structure to historical conditions, degree of other types of habitat degradation, etc.) and the biodiversity values of the site (e.g., threatened species and ecosystems, culturally important biodiversity features, ecological processes necessary for maintaining nearby critical habitats).

When delineating modified and natural habitats, clients should not focus on the project site in isolation. The level of anthropogenic impact should be determined with respect to the greater landscape/seascape in which the project is located. In other words, is the project site (or parts of it) located in a disturbed area amidst an otherwise intact landscape? Is the project site (or parts of it) an island of natural habitat within a heavily disturbed or managed landscape? Is the project site located near areas of high biodiversity value (e.g., wildlife refuges, corridors or protected areas)? Or, is the project site located in a mosaic of modified and natural habitats that contain various degrees of biodiversity values of importance to conservation? The client should be prepared to define its project site in these terms as part of the risks and impacts identification process.

The Nairobi-Nakuru-Mau Summit Highway Expansion and Upgrade Project area was considered within a greater landscape of relevance within the SBSA and LULUCA study. For the former, a landscape of 377,955 ha was considered while for the latter in particular, a massive area (>1.3 M ha) around the proposed project site was integrated in a consideration of land use patterns between 2000, 2010 and 2020 (20 years). The two studies specified therefore provide a context of a general landscape overview of relevant trends in space and time. The overall area can therefore be considered as adequately studied in both space and time and the ability to make predictions is considered as good. The botanical investigation (Orban and Wolfaard, 2021) conducted as part of the baseline work for the project provides an analysis of habitat degradation, habitat fragmentation and habitat condition. The degradation analysis highlights a landscape that retains a reasonable ability to "bounce" back should human driven land use practices be abandoned. This means that at this stage the building blocks for a naturally driven recovery of the landscape from an "agricultural" stage to a "natural" stage remain available. The fragmentation analysis highlights that the landscape is definitely in a fragmented stage, evolving towards the attrition stage when natural habitat remnants/fragments are no longer viable. Finally, the habitat condition analysis shows that 36% of the sites sampled were at a "modified" stage while the remainder still qualified under a natural stage. These three elements of analysis confirm in a separate manner the results inferred from the LULUCA and the SBSA and highlight that both investigations are robust in their inferences.

Based on the approach followed above and items investigated, for the purposes of delineating modified and natural habitats, it is acceptable to consider that the project site was not evaluated in isolation. Indeed, due consideration was given to the level of anthropogenic impact in the greater landscape in which the project is located, and due consideration was given to the time since changes have occurred as the analysis investigated changes between 2000 and 2020, including a mid-point in 2010. This period provides a 20 years' overview, and two reference periods were considered to evaluate whether some trends appear and reverse or whether the trend is one of general persistence in one direction.

In the Nairobi-Nakuru-Mau Summit Highway Expansion and Upgrade Project discrete management unit, the situation is reminiscent of a natural landscape undergoing a rapid transition towards a modified status. As evidenced in the LULUCA study (Mottram and Gaugris, 2021), during the period of analysis the landscape tipped between a position of being in majority a natural landscape to a situation where land managed by humans has become the dominant situation.

Considering the trends highlighted in the LULUCA study, without mitigation measures being developed and levelled at the urban, mining, and especially the agricultural sectors, the outcome is expected to be a continued transition to a state of "generally modified" habitat within the medium term (15 years) perspective, although a change towards modified habitat along the road network may arise over the short to medium term perspective.

From a pure definition perspective, based on the specialist analyses undertaken, the following can be specified:

- The majority of the landscape is characterised by the following statement:
    - Substantial expanses of land (although representing less than 50% of the landscape analysed), to be considered as natural, remain in the landscape. However, these sections of land are most likely defined by the existing conservation area network of the study area or are on the fringes of the study area;
    - The majority (54%) of the landscape can be considered as used for "agricultural" purposes, which although it has an impact on the quality of the landscape, may not necessarily mean that the land has been modified under the IFC PS6 definition.
- The minority of the landscape is characterised by the following statements:
    - There are clear areas of intensively managed modified habitats marked by towns and villages expansion;
    - There are intensively degraded natural habitats zones which may no longer be considered as "natural habitats" as they will no longer have time or the option for recovery to a more natural state, this may be particularly relevant for areas where the land use existed in 2000 and has remained constant;
    - There are lightly degraded patches of land, which might be considered as natural habitat, occurring as a mosaic within the modified looking landscape, which retain a conservation interest and should be considered for conservation activities, however, the fragmentation processes noted for the study area highlight a high need to further include connectivity segments.

PS6 § GN28 (2019 version). Both natural and modified habitats may contain high biodiversity values, thereby qualifying as critical habitat. Performance Standard 6 does not limit its definition of critical habitat to critical natural habitat. An area may just as well be critical modified habitat. The extent of human-induced modification of the habitat is therefore not necessarily an indicator of its biodiversity value or the presence of critical habitat.

In the study area, due to the nature of modified habitat zones that will be proposed, which are likely to follow the road axes, it appears that the existence of critical modified habitat is possible, especially when a connectivity link is required to cross a section of modified habitat.

3.1.2 Modified Habitat

PS6 § 11 (2012 version). Modified habitats are areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition. Modified habitats may include areas managed for agriculture, forest plantations, reclaimed coastal zones, and reclaimed wetlands.

PS6 § 12 (2012 version). This Performance Standard applies to those areas of modified habitat that include significant biodiversity value, as determined by the risks and impacts identification process required in Performance Standard 1. The client should minimize impacts on such biodiversity and implement mitigation measures as appropriate.

PS6 § GN35 (2019 version). Human activity may modify the structure and composition of natural habitats to the degree that non-native species become dominant and/or the natural ecological functions of the habitat fundamentally change. At the extreme, this takes the form of urbanized areas. However, there is a wide spectrum of modified habitats that includes agricultural areas, plantation forestry, and lands partially degraded by a range of other human interventions. The landscape context (for example, fragmentation of surrounding natural habitat, if any) will also influence the degree to which a project site is considered modified. Where there is doubt whether a habitat is modified or natural see paragraph GN39 in this note. See also paragraph GN27, which provides additional context on the assessment of modified and natural habitats on the landscape scale.

PS6 § GN38 (2019 version). The "project" in footnote 5 of Performance Standard 6 refers to the client's project as it is described for proposed financing. Habitat would retain its pre-project modification designation – it would not be considered modified habitat – if it was recently degraded by the client or a third party in anticipation of obtaining lender financing or regulatory approval for the project in which IFC is considering investing. Natural disturbances such as forest fire, hurricane, or tornado affecting a natural habitat would not lead to a modified habitat designation. Where uncertainty over prior modification exists, the client should provide evidence to support why it believes the pre-project habitat modification designation does not apply. Also, as relevant to paragraph 26 on "Sustainable Management of Living Natural Resources," Performance Standard 6 will respect cut-off dates for the conversion of natural habitat as established by internationally recognized voluntary standards, such as the Forest Stewardship Council and the Roundtable on Sustainable Palm Oil.

In the present context, we consider the changes over a 20-year period through the LULUCA study (Mottram and Gaugris, 2021), and recognise that pre-existing agricultural development as well as development of towns and villages had affected 5.3% of the landscape in 2001. As the period evaluated meets the 20 years threshold of permanence[1] considered for the United Nations recommendations in terms of land use change analysis in the context of Reduced Emissions from Deforestation and Degradation (REDD+), as stated by the International Panel on Climate Change (IPCC, 2006), we consider that pre-existing conditions noted to remain as in their original state can justifiably be considered as permanent.

The land use change analysis performed compared the discrete management unit at three points in time separated by 20 years for the extremes: 2000 and 2020. The overwhelming majority of the degradation of the natural habitat observed in the LULUCA study can be considered as part of a long-term process, which highlights that most land use transitions are from a complex to a simpler state, corresponding to degradation of natural habitat into simpler forms of it, some of which can be considered as modified habitat.

Only a micro level area of the landscape (0.36%) is noted as following a transition in the opposite direction over the 20 years period, from a degraded state to a more natural state. The potential for a return to natural state may therefore be subject to the complete removal of anthropogenic influence, an aspect that appears highly unlikely in the current macro-economic situation. The results of the land use change analysis can therefore be considered as representative in terms of timeline for the appearance of modified habitat.

[1] In other words, a land use class that has remained in its status or trend for 20 years can be considered as permanent and fixed in its classification. Any noticeable changes towards a more “natural” state during the 20 years period may support the fact that a reversal is possible and therefore the modification of status is not permanent. This is a different outlook on modified habitat terminology which has been considered for the rewarding of climate positive attitudes in countries.

As such the land cover / land use classes of the land use change analysis presented in Table 1 can be considered for the separation between natural and modified habitat classes to fit the IFC PS6 definition.

Table 1: Suggested separation between modified and natural habitat considering the land use and land use change analysis conducted over the 2000 – 2020 period and including an analysis of the 2000 – 2010 and 2010 – 2020 periods for in between trends.

ID	Land use class	Modified or Natural classification
1	Villages and towns - 2000 - 2020	Habitat considered as modified prior to the 2000 period can clearly be considered as modified habitat – land use unlikely to change over the long-term future. This land use class can only be considered as modified habitat.
2	Mines and major excavations - 2000 - 2020	Habitat considered as modified prior to the 2000 period can clearly be considered as modified habitat – land use unlikely to change over the long-term future. This land use class can only be considered as modified habitat.
3	Cultivation, bare soil and severe deforestation/degradation (with old lands and minor settlements included) - 2000 - 2020	Habitat considered as under “human” management prior to the 2000 period, with a persistence of the land use over a 20-year period considered. This can clearly be considered as modified habitat – land use unlikely to change over the long-term future
4	Plantations - 2000 - 2020 (including degraded or clear-cut plantation areas in 2010 and 2020)	Habitat considered as under “human” management prior to the 2000 period, with a persistence of the land use over a 20-year period considered. Plantation rotation cycles are 25 – 30 years. This can clearly be considered as modified habitat – land use unlikely to change over the long-term future
5	Medium to severe deforestation/degradation and old lands - 2000 - 2020	This is a land use type showing “use” or “disturbance” by people and that has remained in this stage over the 20 years period considered. However, based on the analysis of degradation, fragmentation and habitat condition in the vegetation baseline, this may be able to bounce back naturally to a pre disturbance/use stage. On that basis, this land use class cannot be considered as modified and must be considered as natural.
6	Sparse woodlands and grasslands - 2000 - 2020	This a “natural” land use class that has persisted over the 20 years period in that land use class. This cannot be considered as modified and must be considered as natural.
7	Open to dense woodlands - 2000 - 2020	This a “natural” land use class that has persisted over the 20 years period in that land use class. This cannot be considered as modified and must be considered as natural.
8	Degraded closed woodlands and forests - 2000 - 2020	This is a land use type showing “use” or “disturbance” by people and that has remained in this stage over the 20 years period considered. However, based on the analysis of degradation, fragmentation and habitat condition in the vegetation baseline, this may be able to bounce back naturally to a pre disturbance/use stage. On that basis, this land use class cannot be considered as modified and must be considered as natural.
9	Closed woodlands and forests - 2000 - 2020	This a “natural” land use class that has persisted over the 20 years period in that land use class. This cannot be considered as modified and must be considered as natural.
10	Expansion of villages and towns - 2010	Based on the fact that villages and towns have only expanded since 2000, and considering population growth as well as the impact of road expansion, the expansion of villages of towns and villages is unlikely to be reversed in the medium to long term future. This land use class can only be considered as modified habitat.

ID	Land use class	Modified or Natural classification
11	Expansion of mines and major excavations - 2010	Based on the fact that villages and towns have only expanded since 2000, considering that mines and excavations are linked to towns and villages expansion and considering population growth as well as the impact of road expansion, the expansion of mines and excavations is unlikely to be reversed in the medium to long term future. Moreover, through the nature of the degradation event, the recovery process will be long term should the mine or excavation site be afforded the chance to regenerate towards a more natural state. This land use class can only be considered as modified habitat.
12	Expansion of cultivation, bare soil and severe deforestation/degradation (with old lands and minor settlements included) - 2010	Based on the fact that villages and towns have only expanded since 2000, considering human population growth and new opportunities afforded by the road development, it is clear that the population requires increasing agricultural land to be fed. Although cleared since 2010, this can clearly be considered as modified habitat as the land use is unlikely to change over the long-term future.
13	Expansion of permanent cultivation - 2010	Based on the fact that villages and towns have only expanded since 2000, considering human population growth and new opportunities afforded by the road development, it is clear that the population requires increasing agricultural land to be fed. Although cleared since 2010, land aimed at permanent cultivation is developed for commercial ends and this can clearly be considered as modified habitat as the land use is unlikely to change over the long-term future.
14	Expansion of plantations - 2010 (including degraded or clear cut plantation areas in 2020)	As forestry cycles are typically aiming for periods of 25 – 30 years, land cleared for plantation purposes in 2010 may be harvested in 2035 and may be re-used for another cycle. This habitat – land use is unlikely to change and must be considered as modified habitat.
15	Expansion of medium to severe deforestation/degradation and old lands -2010	This land use class highlights recent expansion of human "use" or human related "disturbance" in a land cover class that was untouched prior to 2000. However, based on the analysis of degradation, fragmentation and habitat condition in the vegetation baseline, this may be able to bounce back naturally to a pre disturbance/use stage. On that basis, this land use class cannot be considered as modified and must be considered as natural.
16	Expansion of degraded closed woodlands and forests - 2010	This land use class highlights recent expansion of human "use" or human related "disturbance" in a land cover class that was untouched prior to 2000. However, based on the analysis of degradation, fragmentation and habitat condition in the vegetation baseline, this may be able to bounce back naturally to a pre disturbance/use stage. On that basis, this land use class cannot be considered as modified and must be considered as natural.
17	Expansion of villages and towns - 2020	Based on the fact that villages and towns have only expanded since 2000 and considering population growth as well as the impact of road expansion, the expansion of villages of towns and villages is unlikely to be reversed in the medium to long term future. This land use class can only be considered as modified habitat.
18	Expansion of mines and major excavations - 2020	Based on the fact that villages and towns have only expanded since 2000, considering that mines and excavations are linked to towns and villages expansion and considering population growth as well as the impact of road expansion, the expansion of mines and excavations is unlikely to be reversed in the medium to long

ID	Land use class	Modified or Natural classification
		term future. Moreover, through the nature of the degradation event, the recovery process will be long term should the mine or excavation site be afforded the chance to regenerate towards a more natural state. This land use class can only be considered as modified habitat.
19	Expansion of cultivation, bare soil and severe deforestation/degradation (with old lands and minor settlements included) - 2020	Based on the fact that villages and towns have only expanded since 2000, considering human population growth and new opportunities afforded by the road development, it is clear that the population requires increasing agricultural land to be fed. Although cleared since 2010, this can clearly be considered as modified habitat as the land use is unlikely to change over the long-term future.
20	Expansion of permanent cultivation - 2020	Based on the fact that villages and towns have only expanded since 2000, considering human population growth and new opportunities afforded by the road development, it is clear that the population requires increasing agricultural land to be fed. Although cleared since 2010, land aimed at permanent cultivation is developed for commercial ends and this can clearly be considered as modified habitat as the land use is unlikely to change over the long-term future.
21	Expansion of plantations - 2020	As forestry cycles are typically aiming for periods of 25 – 30 years, land cleared for plantation purposes in 2020 may be harvested in 2045 and may be re-used for another cycle. This habitat – land use is unlikely to change and must be considered as modified habitat.
22	Expansion of medium to severe deforestation/degradation and old lands - 2020	This is a land use type showing “use” or “disturbance” by people and highlights recent changes from a less degraded to a more advanced stage of degradation since 2010. This does not qualify for a change in the natural habitat designation. Based on the analysis of degradation, fragmentation, and habitat condition in the vegetation baseline, this may be able to bounce back naturally to a pre disturbance/use stage. On that basis, this land use class cannot be considered as modified and must be considered as natural.
23	Expansion of degraded closed woodlands and forests - 2020	This land use class highlights recent expansion of human “use” or human related “disturbance” in a land cover class that was untouched prior to 2010. However, based on the analysis of degradation, fragmentation and habitat condition in the vegetation baseline, this may be able to bounce back naturally to a pre disturbance/use stage. On that basis, this land use class cannot be considered as modified and must be considered as natural habitat.
24	Recovery of sparse woodlands and grasslands - 2020	A recovery pattern is evident, and this highlights that the vegetation if left alone to recover, can do so. This land use class must be considered as natural habitat.
25	Recovery of open to dense woodlands - 2020	A recovery pattern is evident, and this highlights that the vegetation if left alone to recover, can do so. This land use class must be considered as natural habitat.
26	Recovery of closed woodlands and forests - 2020	A recovery pattern is evident, and this highlights that the vegetation if left alone to recover, can do so. This land use class must be considered as natural habitat.
27	Water	This type of land cover class does not show evidence of modification between 2000 and 2020 even though degradation is possible as a result of human impact. This land cover class must be considered as natural habitat.

ID	Land use class	Modified or Natural classification
28	Wetlands	This type of land cover class does not show evidence of modification between 2000 and 2020 even though degradation is possible as a result of human impact. This land cover class must be considered as natural habitat.

3.1.3 Natural Habitat

PS6 § 13 (2012 version). Natural habitats are 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.

PS6 § GN39 (2019 version). The determination of natural habitat will be made using credible scientific analysis of best available information. An assessment and comparison of current and historical conditions should be conducted, and local knowledge and experience should be utilized. Where natural habitats are suspected, a map showing location and extent of natural and modified habitats should be included in the risks and impacts assessment. Natural habitats are not to be interpreted as untouched or pristine habitats. It is likely that the majority of habitats designated as natural will have undergone some degree of historical or recent anthropogenic impact. The question is the degree of impact. 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.

The LULUCA work allows a timeline analysis between 2000 and 2020 and provides an insight of what was "modified" prior to 2000 and remained modified to 2020. Conversely, this analysis also shows that portions of land have remained in a natural state since 2000. Some sections of land that represent naturally occurring vegetation and habitat show recent changes or persisting periods of change, however, based on information gathered through the vegetation baseline work, a potential for regeneration is evident if left alone, demonstrated in the LULUCA by the fact that some sections of land were noted as recovering to a more natural stage. These land use and land cover classes, by virtue of the potential to regenerate qualify as natural habitat and must be considered as such.

A summary map of the natural and modified habitat separation using the above suggestion is presented in Figure 2.

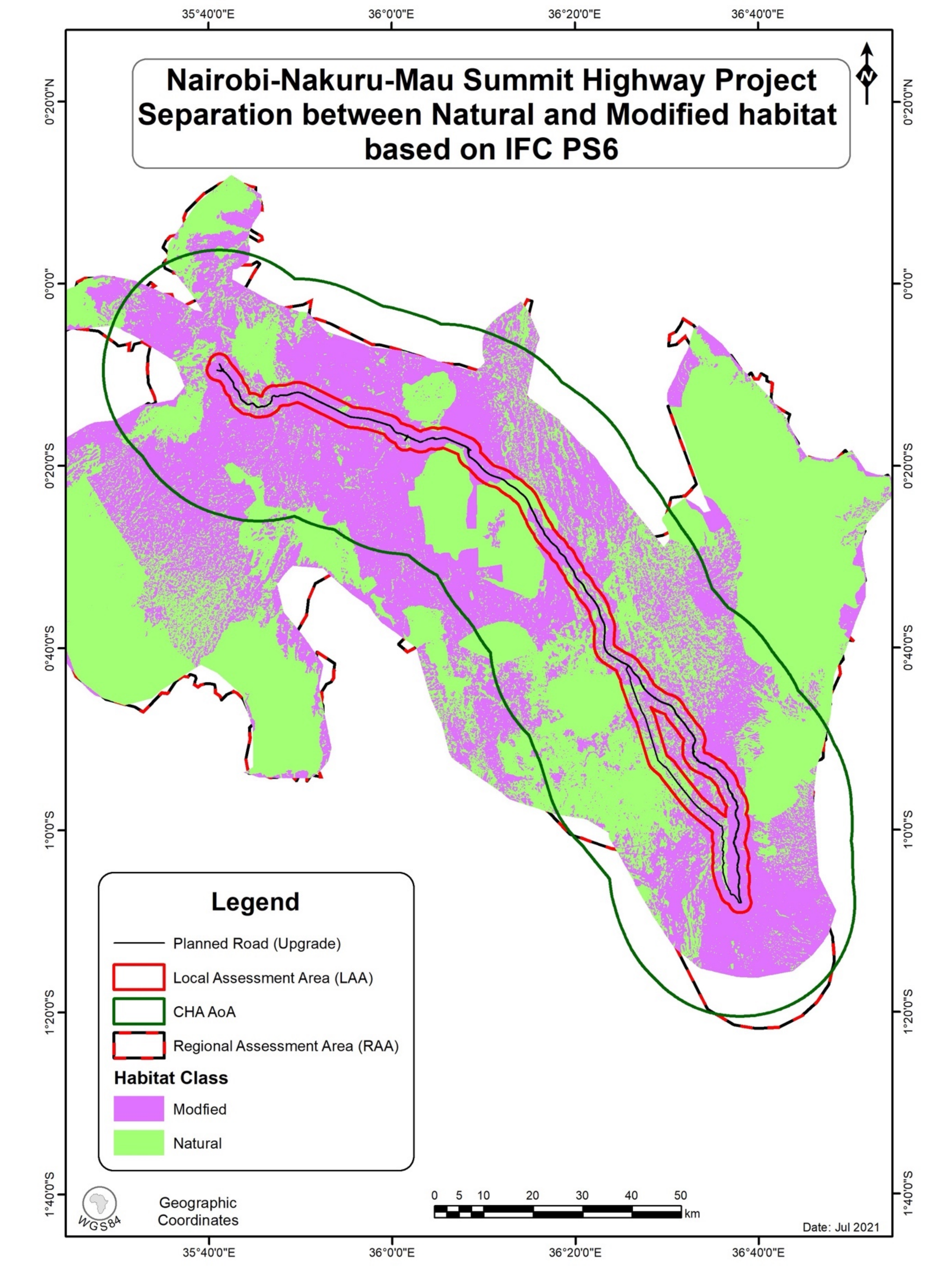


Figure 2. Representation of the separation between Natural and Modified habitat for the landscape of concern. The relevant assessment areas are highlighted as well as the suggested Area of Analysis for Critical habitat, as defined by TBC (2018) and by FFMES (see further below).

3.1.4 Critical Habitat – Criterion 1 to 5 review

PS6 § 16. Critical habitats are areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered species[2]; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes.

PS6 § GN59 (2019 version). The project should identify an ecologically appropriate area of analysis to determine the presence of critical habitat for each species with regular occurrence in the project's area of influence, or ecosystem, covered by Criteria 1-4. The client should define the boundaries of this area taking into account the distribution of species or ecosystems (within and sometimes extending beyond the project's area of influence) and the ecological patterns, processes, features, and functions that are necessary for maintaining them. These boundaries may include catchments, large rivers, or geological features. The client will use this area of analysis to assess applicability of the critical habitat criteria and thresholds (see paragraphs GN70–GN83 of this note) to determine critical habitat for the species and/or ecosystems concerned. Critical habitats boundaries should be equivalent in scale to areas mapped for practical site-based conservation management activities. For some wide-ranging species, critical habitat may be informed by areas of aggregation, recruitment, or other specific habitat features of importance to the species. In all cases, the critical habitat should consider the distribution and connectivity of such features in the landscape/seascape and the ecological processes that support them. Where it can be shown that multiple values have largely overlapping ecological requirements and distributions, a common or aggregated area of critical habitat may be appropriate. The final area(s) of critical habitat against which project impacts will be assessed should be revised based on additional knowledge documented through field work and other assessment after the initial critical habitat assessment has been conducted.

3.1.4.1 Area of Analysis

The preliminary Area of Analysis (AoA) for the Nairobi-Nakuru-Mau Summit Highway Expansion and Upgrade Project is represented by the area (a Discrete Management Unit – DMU) considered under the TBC (2018) study and spans 1,378,329 ha (13,783 km^2). This DMU is now considered as the Regional Assessment Area (RAA) for the project and was re-used for the LULUCA work conducted for the present project and to separate the land between natural and modified states.

While this RAA provides a large-scale vision for the area to understand the regional implications, its use as a blanket area for the application of a critical habitat classification is considered as not practical for a project targeting a road where direct impacts are unlikely to exceed a 2 km distance away from the road itself (Van der Ree, 2015). Hence, adjustments are required. Based on the LULUCA work, within the RAA the furthest distance between a land use class pixel and a clearly human created element (town, village or road) in 2020 is 22.3 km. While the road project is likely to have an indirect influence on increasing traffic, the 2000 – 2020 context highlights that this distance did not change since 2000. The project is therefore considered as unlikely to alter the landscape further than this distance and an adjusted Critical Habitat AoA (CH AoA) representing a distance of 23 km on either side of the road alignment is considered

[2] As listed on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. The determination of critical habitat based on other listings is as follows: (i) If the species is listed nationally / regionally as critically endangered or endangered, in countries that have adhered to IUCN guidance, the critical habitat determination will be made on a project by project basis in consultation with competent professionals; and (ii) in instances where nationally or regionally listed species' categorizations do not correspond well to those of the IUCN (e.g., some countries more generally list species as "protected" or "restricted"), an assessment will be conducted to determine the rationale and purpose of the listing. In this case, the critical habitat determination will be based on such an assessment.

as an adequate representation of the risk zone of the project. Within the CH AoA, key catchments and conservation areas will require specific evaluation (Figure 3).

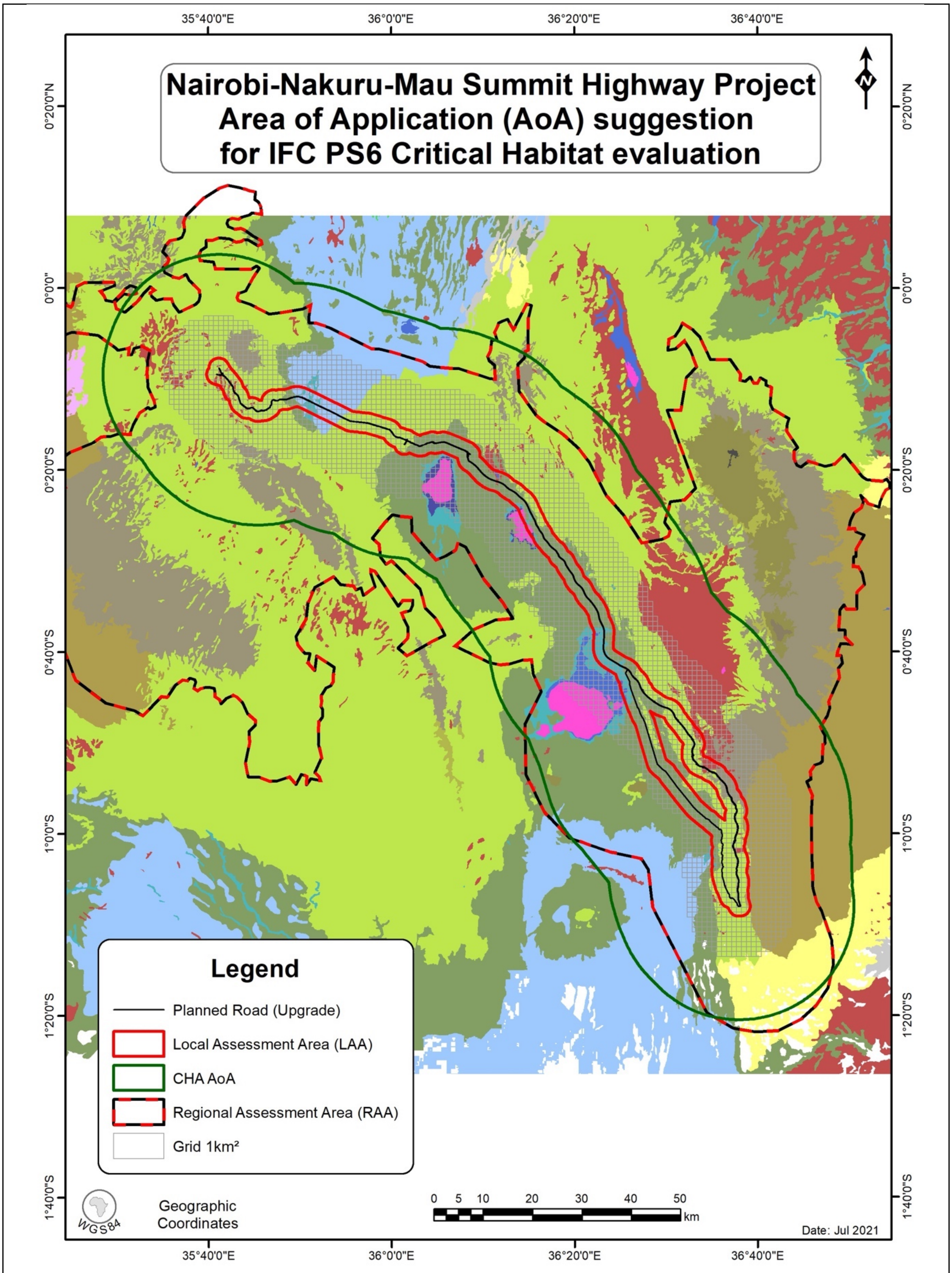


Figure 3: AoA representation based on the suggestion from FFMES. The former AoA by TBC (2018) is highlighted for context.

GN60 (2019 version). Specific methods for the assessment of biodiversity will inherently be project- and site-specific, considering the breadth of ecosystems, the various forms of critical habitat, and the range of species covered under Performance Standard 6. Guidance Note 6 therefore does not provide methodologies for conducting biodiversity assessments. Instead, the three broad-level steps outlined below direct the client in designing the overall scope of a critical habitat assessment.…

GN60 (2019 version) Step 1 - Stakeholder Consultation/Initial Literature Review
Aim: To obtain an understanding of biodiversity within the landscape from the perspective of all relevant stakeholders.
Process: Field consultation exercises and desktop research.

This step has been completed in parts through the body of work undertaken by FFMES and presented in the general reports on the biodiversity baselines conducted. Additional work has been conducted within the AoA by WSP Canada and the national consultancy Norken International Ltd.

GN61 (2019 version) Step 2: Field Data Collection and Verification of Available Information
Aim: To collect field data and verify available detailed information necessary for the critical habitat assessment.
Process: Engage qualified specialists to collect field data as necessary both within and outside of the ecologically appropriate area of analysis (see GN59).

A body of work has been undertaken by FFMES to gather field data by competent experts / qualified specialists. Some limitations apply to the work and are provided by FFMES in the respective reports, in terms of methodology used for the field studies or analysis. However, the body of work is considered as representative, in terms of spatial and species attributes investigated, indeed:

- Spatially:
  - >10% of the relevant LAA portion of the landscape has been investigated through physical field surveys;
  - >15% of the relevant LAA portion of the landscape has been visited in addition to the area sampled with physical surveys, which thereby provides an indication of the validity of the sampling portion for the greater landscape
  - Based on the above, a spatially representative body of work has been undertaken in the ecologically appropriate area of analysis.
- Species attributes:
  - All reports on biodiversity attributes highlight that the species accumulation curves have reached either an asymptote state at the broad habitat class level, or the point where additional work is considered as no longer cost efficient

Based on the above, the effort conducted to investigate the landscape is considered as representative (Bourgeron et al. 2001 minimum target of 5% of the landscape being visited was exceeded) while the species representativeness levels for each field investigated meet or exceed the minimum thresholds of representativeness commonly used for such investigations (Gulison et al. 2015).

GN62 (2019 version) Step 3: Critical Habitat Determination
Aim: Determine whether the project is situated in critical habitat.
Process: Analysis and interpretation of the desktop and field data collected.

The present body of work represents the definition of critical habitat for the Nairobi-Nakuru-Mau Summit Highway Expansion and Upgrade Project area.

Critical Habitat Definition

PS6 § GN53 (2019 version). The critical habitat definition presented in paragraph 16 of Performance Standard 6 is in line with criteria captured from a range of definitions of priority habitat for biodiversity conservation in use by the conservation community and incorporated in related governmental legislation and regulations.

Critical habitats are areas of high biodiversity value that include at least one or more of the five values specified in paragraph 16 of Performance Standard 6 and/or other recognized high biodiversity values. There is no one criterion that is more important than any other for making critical habitat designations or for determining compliance with Performance Standard 6.

For ease of reference, these values are referred to as "critical habitat criteria" for the remainder of this document. Each criterion is described in detail in paragraphs GN70–GN83. Critical habitat criteria are as follows and should form the basis of any critical habitat assessment:

- *Criterion 1: Critically Endangered (CR) and/or Endangered (EN) species*
- *Criterion 2: Endemic or restricted-range species*
- *Criterion 3: Migratory or congregatory species*
- *Criterion 4: Highly threatened and/or unique ecosystems*
- *Criterion 5: Key evolutionary processes*

PS6 § GN56 (2012 version). The determination of critical habitat, however, is not necessarily limited to these criteria. Other recognized high biodiversity values might also support a critical habitat designation, and the appropriateness of this decision would be evaluated on a case-by-case basis. Examples are as follows:

- *Areas required for the reintroduction of CR and EN species and refuge sites for these species (habitat used during periods of stress (e.g., flood, drought or fire).*
- *Ecosystems of known special significance to EN or CR species for climate adaptation purposes.*
- *Concentrations of Vulnerable (VU) species in cases where there is uncertainty regarding the listing, and the actual status of the species may be EN or CR.*
- *Areas of primary/old-growth/pristine forests and/or other areas with especially high levels of species diversity.*
- *Landscape and ecological processes (e.g., water catchments, areas critical to erosion control, disturbance regimes (e.g., fire, flood)) required for maintaining critical habitat.*
- *Habitat necessary for the survival of keystone species.*
- *Areas of high scientific value such as those containing concentrations of species new and/or little known to science.*

Table 2 summarises the criteria qualifying biodiversity features for the study area. However, some of the choices made for each of the five criteria require further justification and are thus presented below.

3.1.4.2 Criteria 1

This is a direct listing for species that have been either observed or are considered likely to occur based on the IUCN lists and available supporting literature for the region of interest. The species are listed in Table 2.

Mammals

Nubian giraffe (*Giraffa camelopardalis camelopardalis*) (CR)

The critically endangered Nubian giraffe was encountered on Soysambu Conservancy. There are currently only 800 individuals of this species in Kenya out of a global population of 3000, the majority of which are resident extralimitally in Kenya due to reintroduction efforts. Indeed, Soysambu Conservancy has in the past acted as a reintroduction site for this species. The Nubian giraffe species, into which the Rothschild's giraffe species was incorporated in 2016, is now categorised as 'critically endangered' by the IUCN's Red List – owing to a 95% reduction in the species' population over the last 30 years (Giraffe Conservation Foundation, 2021).

Across sub-saharan Africa, giraffe species have been particularly negatively affected by habitat degradation, land transformation and human-wildlife conflict. However, giraffe populations have also been the target of illegal meat harvesting and tail hair harvesting. Nubian giraffe populations specifically have been negatively affected by habitat fragmentation thus providing sufficient protected areas is of key importance for the survival of this species. Based on reintroduction efforts in Kenya, Nubian giraffe metapopulation management is now crucial to prevent inbreeding of isolated populations (Giraffe Conservation, 2021). Based on its key importance for Nubian giraffes, the Soysambu Conservancy can be considered as 'critical habitat' (Appendix 1, Figure A).

Masai giraffe (*Giraffa camelopardalis tippelskirchi*) (EN)

The endangered Masai giraffe was also encountered multiple times in this study, both in Marula Estates and along the edges of Lake Naivasha. This species, into which the Thornicroft's giraffe was incorporated in 2016, is generally found to the south and west of Kenya in the Masai Mara National Reserve. It is considered endangered due to a 49-50% reduction in its population over the last 30 years and most recent estimates put the population at around 35,000 individuals. Similar to the Nubian giraffe, the causes of population reduction are habitat degradation, human encroachment and illegal harvesting. Specifically in Kenya, the population of Masai giraffe reduced from 32,000 in 1977 to 12,000 in 2015. In the south of Kenya and north of Tanzania, giraffe have been specifically targeted by poachers using snares. Aside from their use as a source of meat, giraffe bones have also been mistakenly purported to cure HIV/AIDS. According to Kenyan law, giraffes are completely protected and the hunting of them is prohibited (Bolger et al. 2019). While Marula Estates provides valuable habitat, locations further south of the study area support larger and more important concentrations of this species and thus Marula Estates is not considered to be of global importance for the survival of Masai giraffe.

African savanna elephant (*Loxodonta africana*) (EN)

In the far east of the study area, evidence of the presence of African savanna elephants (*Loxodonta africana*) was recorded. This species is currently listed as endangered by the IUCN's red list. The global population of the species is considered to have declined by more than 50% in the last 75 years, a trend which is currently believed to be irreversible. Such a fate is based upon the continued transformation of habitat and severe conflict with humans in the form of ivory poaching. Where poaching was particularly severe in Kenya between 1970 and 1989, elephant populations experienced somewhat of a reprieve in the following decades, however incidence of poaching has re-emerged in recent years (Gobush et al. 2021). Elephants are particularly important in terms of ecosystem service provision and for socio-economic development in Kenya based on the tourism income which can be generated through their presence. However, the largest and most important populations of elephants are located outside of the study area in Kenya. Based on the limited indicators of elephant presence identified it is believed that the Nairobi-Nakuru-Mau Summit study area is not of global importance for this species.

Birds

Vultures

Five species of vulture were noted in this study, however only two species (Rüppell's vulture (*Gyps ruppelli*) and white-backed vulture (*Gyps africanus*)) were observed during the field surveys. Three further species (hooded vulture (*Necrosyrtes monachus*), Egyptian vulture (*Neophron percnopterus)* and lappet faced vulture (*Torgos tracheliotos*)) are considered to be present in the region. Vultures present a complex critical habitat designation based on their scavenger nature and lack of reliance on one particular feeding area, but rather the maintenance of regular carrion. Establishing protected wildlife areas is thought to be an effective route to protect vultures from extinction (Virani et al. 2010). These protected areas must either in combination or separately support both breeding and scavenging. The encounter of vultures feeding in Soysambu Conservancy suggests that it is a key vulture feeding site and therefore supports the survival of multiple vulture species (Appendix 1, Figure B).

Rüppell's vulture (*Gyps rueppelli*) (CR)

The Rüppell's vulture is classified as critically endangered by the IUCN's Red List. The species has experienced declining populations throughout its entire range (Ogada et al. 2016). These declines can be attributed to land transformation and loss of habitat, but are also linked to poisoning, human use for medicine or meat, loss of nesting sites, and declining availability of food sources. Poisoning is currently thought to be the most serious threat to all vulture populations in Africa, although they are not usually the intended target. Killing of Rüppell's vultures for use in traditional medicine has also greatly contributed to the rapid population declines. In many African cultures, vultures are used for traditional medicine and magic related to superstitions that they are clairvoyant and can be used to increase a child's intelligence. Rüppell's vultures are considered breeding residents across Soysambu Conservancy, Marula Estates and the Lake Naivasha region. Based on the IUCN classification of this species and the sightings of this species, this area can be considered globally important for this species (Appendix 1, Figure B).

White-backed vulture (*Gyps africanus*) (CR)

The white-backed vulture is classified as critically endangered by the IUCN's Red List. This species has suffered from severe declines in its population across many parts of its range. Such declines are attributed to habitat transformation, reductions in ungulate populations, persecution and poisoning (BirdLife International, 2018). The current global population is estimated to be around 270,000 individuals, but research suggests that this is only 10% of what the population stood at 55 years ago. Indeed, in the Laikipia region of central Kenya Ogada and Keesing (2010) showed a 69% reduction in the population of white backed vultures between 2001 and 2003. The species is primarily a lowland species, showing a particular preference for *Acacia* dominated sites. The majority of the Nairobi-Nakuru-Mau Summit regional assessment area is considered to be non-breeding habitat for white-backed vultures. However, between Lake Nakuru National Park and Lake Naivasha, white backed vultures are considered resident and thus this landscape is likely to be of global importance for the survival of this species (Appendix 1, Figure B).

Hooded vulture (*Necrosyrtes monachus*) (CR)

The critically endangered hooded vulture was expected to be observed in the study area however no observations were recorded. Recent research suggests that the population of this species has suffered greatly from poisoning, illegal trade to supply the traditional medicine market and electrocution. This is in addition to the threats arising from habitat loss and landscape transformation. The lack of sightings of this species during both field seasons, supported by relatively recent evidence which indicates that hooded vultures may now be extinct from the immediate Nairobi-Nakuru-Mau Summit study area mean that this landscape cannot be considered globally important for this species (BirdLife International, 2017b).

Lappet faced vulture (*Torgos tracheliotos*) (EN)

The endangered lappet faced vulture was not observed during the field surveys, however distribution records suggest that this species is dependent on the area around Lake Elementaita for breeding purposes. This species has suffered severe declines in its population and while it is widely distributed it has experienced multiple localised extinctions and the global adult population is now believed to lie at around 5,700 individuals. The lappet-faced vulture is particularly susceptible to poisoning and evidence has shown that accidental poisoning via strychnine and carbofuran have contributed to the declines in populations. While the poisoning may have been accidental there is evidence to show that links with the illegal trade for traditional medicine have affected this species severely (BirdLife International, 2019). While the area around Lake Elementaita is considered to be important for this species, there is still an extensive area where this species is believed to breed and thus it is unlikely that this site could be considered as globally important for the lappet faced vulture.

Egyptian vulture (*Neophron percnopterus*) (EN)

The endangered Egyptian vulture was not observed during the field surveys but was expected to be sighted. Distribution records suggest that this species is extant in the study area, however is non-breeding. The species has a vast range which covers Saharan Africa, east Africa, Europe and Asia. This species has seen rapid declines in its population, in Africa such declines have been attributed to the loss of wild ungulates caused by habitat transformation as a result of changing agricultural practices (BirdLife International, 2019b). Based on the lack of sightings of this species in the study area, its wide-ranging distribution and lack of breeding habitat in Kenya the study area is unlikely to be considered globally important for the Egyptian vulture.

Steppe Eagle (*Aquila nipalensis*) (EN)

The endangered Steppe eagle was observed on Marula Estates during the study period. The species' range extends from southern Africa, into Europe and across Asia. The species is a palearctic migrant and spends winter in southern and eastern Africa. The greatest population declines for this species have been observed in Europe where the species has been negatively affected by habitat transformation and power line collisions (BirdLife International, 2020). The wide range of this species means that it is highly unlikely that the Nairobi-Nakuru-Mau Summit study area is of global importance for its survival.

Bateleur (*Terathopius ecaudatus*) (EN)

The endangered Bateleur was observed on Marula Estates in February 2021. This species has an extensive range across a significant portion of sub-saharan Africa. However, it is classified as endangered due to rapid declines in population numbers over the last 46 years. Such declines are attributed to poisoning (both incidental and deliberate) and nest disturbance. In Kenya, habitat loss is considered to be a key driver in the reduction of this species (BirdLife International, 2020b). Based on the single observation and wide range of the species it is considered highly unlikely that the study area is of global importance for the survival of this species.

Martial Eagle (*Polemaetus bellicosus*) (EN)

Similar to the Bateleur, the endangered Martial eagle was observed once during the study period. This species has an extensive distribution, across almost all of sub-saharan Africa, except for the central African rainforests. It is classified as endangered based upon a rapid population decline, considered to be the result of poisoning (both incidental and deliberate), prey reduction and pollution (BirdLife International, 2020c). Considering the single observation of this species during the study period and its far-reaching distribution, the study area is not considered to be of global importance for its survival.

Basra Reed Warbler (*Acrocephalus griseldis*) (EN)

The Basra reed warbler is classified as endangered by the IUCN's Red List based on population declines resulting from habitat drainage, poor water management and drought. The species breeds in the middle east, but migrates to eastern Africa for winter (BirdLife International, 2017). The southern half of the study area, extending from Naivasha to Nairobi is a site of residence for the species during winter, however is not believed to be of global importance for the species.

Malagasy Pond Heron (*Ardeola idea*) (EN)

The Malagasy (Madagascar) pond heron is an endangered species with a declining population. Its main breeding range covers Madagascar, Réunion and the Seychelles, however individuals have been recorded as present (yet non-breeding) in Kenya. The species was not observed during the study period, however previous records indicated its presence particularly around the Soysambu Conservancy. The study area does not comprise part of the species breeding area and it is considered highly unlikely to harbour globally important populations of this species (BirdLife International, 2016).

Grey Crowned Crane (*Balearica regulorum*) (EN)

Large groups of the endangered grey crowned crane were observed on Marula Estates during the study period. The species has a large range which covers much of the northern section of southern Africa and parts of central-eastern Africa. While the species has recorded significant declines across its range, one of the largest remaining populations is in Kenya where 10,000 to 12,500 individuals are believed to be resident (BirdLife International, 2016b). The large populations of grey-crowned cranes which were observed foraging in the Marula Estates suggest that this landscape is of importance to the species, however, based on the large distribution of this species, Marula Estates is not believed to be of global importance for the grey crowned crane.

Sharpe's Longclaw (*Macronyx sharpei*) (EN)

The endangered Sharpe's longclaw was not observed in the study period, yet was expected. It has a significantly limited range and is endemic to Kenya. Its main resident sites are Mau Narok and the eastern flanks of Mt Kenya (BirdLife International, 2016c). The species is particularly dependent on grasslands, a habitat type which has reduced greatly due to land transformation for agricultural purposes. It thus appears that the eastern side of the study area, reaching into the Aberdare Mountain range is of global importance to this species (Appendix 1, Figure C).

Secretary Bird (*Sagittarius sepentarius*) (EN)

The secretary bird is an endangered species with a decreasing population. The species was recorded on both Soysambu Conservancy and Marula Estates. Its population has been negatively affected by the conversion of land to urbanised areas and in Kenya specifically, suitable habitat for this species is being converted rapidly for commercial purposes. The species has an extensive range which covers almost all of sub-saharan Africa, aside from the central African rainforests and coastal west Africa. The study area is thus not considered to be of global importance for the species survival (BirdLife International, 2020d).

Table 2: Summary table of the Critical Habitat Qualifying Features as per IFC PS6 (2012 and 2019 versions)

PS6 Criteria	Biodiversity feature				IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
	Group	Domain	Scientific name	Common name						
1: Critically Endangered and/or Endangered species, subspecies and subpopulations	Mammals	Terrestrial	*Giraffa camelopardalis Ssp camelopardalis (formerly rothschildi)*	Giraffe (Nubian, formerly Rotschild's)	CR	Yes		Based on Fennessy et al. (2016) the Rothschild's giraffe should be subsumed into the nominate Nubian giraffe. This change in classification suggests an uplisting of the IUCN status from VU to CR for this sub species is likely although it does not yet reflect on the IUCN website. The Giraffe Conservation Foundation lists the Nubian giraffe as critically endangered. The species was encountered in the Soysambu conservancy	Yes	Soysambu Conservancy supports a globally important concentration of the critically endangered Nubian giraffe.
			Loxodonta africana	African savanna elephant	EN	Yes		Species noted by a relatively fresh dung evidence (<3 months old) in the Gatamaiyo Forest Nature Reserve (within the RAA)	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Giraffa camelopardalis Ssp Tippelskirchi	Giraffe (Masai)	EN	Yes		The species was encountered in the Marula estates and along the edges of lake Naivasha.	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Oryx beisa spp callotis	Fringe-eared Oryx	VU (decreasing)	Yes		This species was encountered in the Marula estates	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Panthera pardus	Leopard	VU (decreasing)	Yes		This species was recorded via camera trapping on Marula estates	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
	Birds	Terrestrial	*Gyps africanus*	White-backed Vulture	CR	Yes		The species was encountered in the Soysambu Conservancy	Yes	Soysambu Conservancy supports a globally important concentration of the critically endangered white-backed vulture
			Necrosyrtes monachus	Hooded vulture	CR	No	IUCN (2021)	Expected not observed	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Gyps rueppelli	Rüppell's Vulture	CR	Yes		The species was encountered in the Soysambu Conservancy and observed in the Marula Estates	Yes	Soysambu Conservancy supports a globally important concentration of the critically endangered Rüppell's vulture
			Neophron percnopterus	Egyptian Vulture	EN	No	IUCN (2021)	Expected not observed	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Torgos tracheliotos	Lappet-faced Vulture	EN	No	IUCN (2021)	Expected not observed	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Aquila nipalensis	Steppe Eagle	EN	Yes		The species was observed in the Marula Estates	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Terathopius ecaudatus	Bateleur	EN	Yes		A single observation of the species was recorded in February 2021 on Marula Estates	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Acrocephalus griseldis	Basra Reed Warbler	EN	No	IUCN (2021)	Expected not observed	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Ardeola idea	Malagasy Pond Heron	EN	No	IUCN (2021)	Expected not observed	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Balearica regulorum	Grey crowned crane	EN	Yes		Several observations of the species in large groups, particularly in Marula Estates and at Manguo Pond	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Macronyx sharpei	Sharpes Longclaw	EN	No	IUCN (2021)	Expected not observed	Yes	The eastern side of the study area, reaching into the Aberdare Mountain range is of global importance to this species
			Sagittarius sepentarius	Secretary bird	EN	Yes		Several individuals observed on both Marula Estates and Soysambu Conservancy	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Polemaetus bellicosus	Martial Eagle	EN	Yes		One individual was observed during the February survey	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Prionops poliolophus	Abbot's Starling	VU (decreasing)	No	IUCN (2021)	Expected not observed	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Falco concolor	Sooty Falcon	VU (decreasing)	Yes		A pair were observed at Soysambu Conservancy	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Bucorvus leadbeateri	Southern Ground Hornbill	VU (decreasing)	Yes		The species was observed at Soysambu Conservancy	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
			Aquila rapax	Tawny Eagle	VU (decreasing)	Yes		The species was observed in Marula Estates and along the A8 South Highway	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
	Plants	Terrestrial	*Ansellia africana*	Leopard Orchid	VU(decreasing)	Yes		Recorded in evergreeen and semi-evergreen bushland and thicket habitat	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species
	Amphibians	Terrestrial	*Mertensophryne lonnbergi*	Lönnberg's Forest Toad	VU (decreasing)	No	IUCN (2021)	Recorded in study area	No	The Nairobi-Nakuru-Mau Summit region does not support a globally important concentration of this species

PS6 Criteria	Biodiversity feature				IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
	Group	Domain	Scientific name	Common name						
2: Endemic and/or Restricted-range species	Mammals	Terrestrial	*Eudorcas nasalis*	Serengeti Thomson's Gazelle	LC	Yes		The sub-species is considered range restricted	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Madoqua cavendishi	Cavendish's Dik-dik	LC	Yes		The sub-species is considered range restricted	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Alcelaphus cokii	Kongoni	LC	Yes		The sub-species is considered range restricted	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Damaliscus jimela	Serengeti Topi	VU (decreasing)	Yes		The sub-species is considered range restricted	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Connochaetes mearnsi	Serengeti White-bearded Wildebeest	LC	Yes		The sub-species is considered range restricted	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Cephalophus johnstoni/harveyi	Johnston's/Harvey's Duiker	LC	Yes		The sub-species is considered range restricted	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
	Birds	Terrestrial	*Cisticola hunteri*	Hunter's Cisticola	LC	Yes		The species is restricted to the Kenyan Mountains Endemic Bird Area	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Euplectes jacksoni	Jackson's Widowbird	NT	Yes		The species is restricted to the Kenyan Mountains Endemic Bird Area	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Prionops poliolophus	Grey-crested helmetshrike	NT	Yes		The species is restricted to the Serengeti Plains Endemic Bird Area	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Zosterops kikuyuensis	Kikuyu White-eye	LC	Yes		The species is endemic to Kenya	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
	Herpeto-fauna	Terrestrial	*Phrynobatrachus keniensis*	Kenya River Frog	LC	Yes		The species is endemic to Kenya	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Hyperolius montanus	Mountain Reed Frog	LC	No	IUCN (2021)	This species is endemic to the Kenyan highlands	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Mertensophryne lonnbergi	Lönnberg's Forest Toad	VU	Yes		This species is endemic to the Kenyan highlands	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Mertensophryne mocquardi	Mocquards Toad	DD	No	IUCN (2021)	This species is endemic to Kenya	No	Despite unclear distribution, the Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Hyperolius cystocandicans	Tigoni Reed Frog	NT	No	IUCN (2021)	The species is endemic to the Kenyan highlands	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Phrynobatrachus kinangopensis	Kinangop River Frog	VU	No	IUCN (2021)	This species is endemic to the Kenyan highlands	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Trioceros jacksonii	Jackson's Three-horned Chameleon	LC	Yes		This species is range restricted	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
			Bitis worthingtoni	Kenya Horned Viper	VU	No	IUCN (2021)	The species is endemic to the Gregory Rift Valley in Kenya	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species
	Freshwater Ecology	Terrestrial	*Bulinus permembranaceus*		VU	Yes		This species is endemic to the Aberdare Range, specifically the Kinangop Plateau and the Mau Escarpment	No	The Nairobi-Nakuru-Mau Summit region does not regularly hold >10% of the global population of this species

PS6 Criteria	Biodiversity feature				IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
	Group	Domain	Scientific name	Common name						
3: Migratory and/or congregatory species	Birds	Terrestrial	*Aquila heliaca*	Eastern Imperial Eagle	VU (decreasing)	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Aquila nipalensis	Steppe Eagle	EN	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Butastur rufipennis	Grasshopper Buzzard	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Buteo buteo	Common Buzzard	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Buteo rufinus	Long-legged Buzzard	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Circus aeruginosus	Western Marsh Harrier	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Circus macrourus	Pallid Harrier	NT	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Circus pygargus	Montagu's Harrier	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Clanga pomarina	Lesser Spotted Eagle	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Hieraaetus pennatus	Booted Eagle	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Hieraaetus wahlbergi	Wahlberg's Eagle	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Milvus aegyptius	Yellow-billed Kite	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Milvus migrans	Black Kite	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Pernis apivorus	European Honey Buzzard	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Acrocephalus arundinaceus	Great Reed Warbler	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Acrocephalus griseldis	Basra Reed Warbler	EN	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature				IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
	Group	Domain	Scientific name	Common name						
			Acrocephalus palustris	Marsh Warbler	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Acrocephalus schoenobaenus	Sedge Warbler	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Acrocephalus scirpaceus	Eurasian Reed Warbler	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Hippolais icterina	Icterine Warbler	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Iduna pallida	Eastern Olivaceous Warble	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Halcyon leucocephala	Grey-headed Kingfisher	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Ispidina picta	African Pygmy Kingfisher	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Anas acuta	Northern Pintail	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Anas crecca	Eurasian Teal	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Aythya fuligula	Tufted Duck	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Dendrocygna bicolor	Fulvous Whistling Duck	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Netta erythrophthalma	Southern Pochard	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Spatula clypeata	Northern Shoveler	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Spatula querquedula	Garganey	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Apus apus	Common Swift	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Apus horus	Horus Swift	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature Group	Domain	Scientific name	Common name	IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
			Tachymarptis melba	Alpine Swift	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Ardeola idae	Malagasy Pond Heron	EN	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Ixobrychus minutus	Little Bittern	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Ixobrychus sturmii	Dwarf Bittern	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Campephaga flava	Black Cuckooshrike	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Caprimulgus europaeus	European Nightjar	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Caprimulgus inornatus	Plain Nightjar	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Charadrius alexandrinus	Kentish Plover	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Charadrius asiaticus	Caspian Plover	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Charadrius dubius	Little Ringed Plover	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Charadrius hiaticula	Common Ringed Plover	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Charadrius leschenaultii	Greater Sand Plover	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Charadrius mongolus	Lesser Sand Plover	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Pluvialis squatarola	Grey Plover	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Ciconia abdimii	Abdim's Stork	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Ciconia ciconia	White Stork	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature Group	Domain	Scientific name	Common name	IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
			Ciconia nigra	Black Stork	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Coracias garrulus	European Roller	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Eurystomus glaucurus	Broad-billed Roller	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Chrysococcyx caprius	Diederik Cuckoo	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Chrysococcyx klaas	Klaas's Cuckoo	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Clamator glandarius	Great Spotted Cuckoo	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Clamator jacobinus	Jacobin Cuckoo	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Clamator levaillantii	Levaillant's Cuckoo	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Clanga clanga	Greater Spotted Eagle	VU (decreasing)	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Cuculus canorus	Common Cuckoo	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Cuculus clamosus	Black Cuckoo	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Cuculus gularis	African Cuckoo	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Cuculus rochii	Madagascan Cuckoo	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Cuculus solitarius	Red-chested Cuckoo	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Falco amurensis	Amur Falcon	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Falco concolor	Sooty Falcon	VU (decreasing)	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature Group	Domain	Scientific name	Common name	IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
			Falco naumanni	Lesser Kestrel	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Falco peregrinus	Peregrine Falcon	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Falco subbuteo	Eurasian Hobby	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Falco tinnunculus	Common Kestrel	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Glareola pratincola	Collared Pratincole	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Delichon urbicum	Common House Martin	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Hirundo rustica	Barn Swallow	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Riparia riparia	Sand Martin	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Lanius collurio	Red-backed Shrike	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Lanius isabellinus	Isabelline Shrike	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Lanius minor	Lesser Grey Shrike	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Lanius phoenicuroides	Red-tailed Shrike	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Chlidonias hybrida	Whiskered Tern	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Chlidonias leucopterus	White-winged Tern	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Chroicocephalus genei	Slender-billed Gull	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Chroicocephalus ridibundus	Black-headed Gull	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature Group	Domain	Scientific name	Common name	IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
			Gelochelidon nilotica	Gull-billed Tern	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Larus fuscus	Lesser Black-backed Gull	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Locustella fluviatilis	River Warbler	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Luscinia megarhynchos	Common Nightingale	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Merops albicollis	White-throated Bee-eater	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Merops apiaster	European Bee-eater	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Merops nubicus	Northern Carmine Bee-eate	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Merops persicus	Blue-cheeked Bee-eater	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Merops superciliosus	Olive Bee-eater	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Anthus campestris	Tawny Pipit	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Anthus cervinus	Red-throated Pipit	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Anthus trivialis	Tree Pipit	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Motacilla alba	White Wagtail	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Motacilla cinerea	Grey Wagtail	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Motacilla flava	Western Yellow Wagtail	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Ficedula semitorquata	Semicollared Flycatcher	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature Group	Domain	Scientific name	Common name	IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
			Irania gutturalis	White-throated Robin	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Monticola saxatilis	Common Rock Thrush	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Muscicapa striata	Spotted Flycatcher	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Oenanthe isabellina	Isabelline Wheatear	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Oenanthe oenanthe	Northern Wheatear	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Oenanthe pileata	Capped Wheatear	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Oenanthe pleschanka	Pied Wheatear	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Phoenicurus phoenicurus	Common Redstart	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Saxicola rubetra	Whinchat	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Oriolus auratus	African Golden Oriole	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Oriolus oriolus	Eurasian Golden Oriole	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Pandion haliaetus	Western Osprey	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Coturnix coturnix	Common Quail	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Coturnix delegorguei	Harlequin Quail	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Excalfactoria (=Synoicus) adansonii	Blue Quail	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Phylloscopus collybita	Common Chiffchaff	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature				IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
	Group	Domain	Scientific name	Common name						
			Phylloscopus sibilatrix	Wood Warbler	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Phylloscopus trochilus	Willow Warbler	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Jynx torquilla	Eurasian Wryneck	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Quelea quelea	Red-billed Quelea	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Aenigmatolimnas marginalis	Striped Crake	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Crecopsis egregia	African Crake	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Crex crex	Corn Crake	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Paragallinula angulata	Lesser Moorhen	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Porphyrio alleni	Allen's Gallinule	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Porzana porzana	Spotted Crake	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Zapornia pusilla	Baillon's Crake	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Rostratula benghalensis	Greater Painted-snipe	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Sarothrura boehmi	Streaky-breasted Flufftail	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Actitis hypoleucos	Common Sandpiper	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Arenaria interpres	Ruddy Turnstone	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Calidris alba	Sanderling	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature				IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
	Group	Domain	Scientific name	Common name						
			Calidris ferruginea	Curlew Sandpiper	NT	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Calidris minuta	Little Stint	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Calidris pugnax	Ruff	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Calidris temminckii	Temminck's Stint	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Gallinago gallinago	Common Snipe	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Gallinago media	Great Snipe	NT	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Limosa limosa	Black-tailed Godwit	NT	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Lymnocryptes minimus	Jack Snipe	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Numenius arquata	Eurasian Curlew	NT	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Numenius phaeopus	Eurasian Whimbrel	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Tringa erythropus	Spotted Redshank	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Tringa glareola	Wood Sandpiper	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Tringa nebularia	Common Greenshank	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Tringa ochropus	Green Sandpiper	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Tringa stagnatilis	Marsh Sandpiper	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Tringa totanus	Common Redshank	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.

PS6 Criteria	Biodiversity feature Group	Domain	Scientific name	Common name	IUCN[1]	Confirmed present in AoA	Source if not confirmed	Note on inclusion - species may not have been observed but presence may be possible - precautionary approach	CH criteria met	Reasoning for CH qualification or not
			Otus scops	Eurasian Scops Owl	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Cinnyricinclus leucogaster	Violet-backed Starling	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Creatophora cinerea	Wattled Starling	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Curruca communis	Common Whitethroat	LC	No	IUCN (2021)	Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Sylvia atricapilla	Eurasian Blackcap	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Sylvia borin	Garden Warbler	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
			Upupa epops	Eurasian Hoopoe	LC	Yes		Migrant	No	The Nairobi-Nakuru-Mau Summit region does not regularly sustain >1% of the global population or support >10% of the global population in times of stress.
4: Highly threatened and/or unique ecosystems		Terrestrial				Yes		According to the Kenya Wildlife Service, Lake Elementaita, Marula Estates, Lake Nakuru, Soysambu Conservancy and the Mau Forest Complex are all considered to be endangered ecosystems (Kenya Wildlife Service, 2021).	Yes	Lake Elementaita, Marula Estates, Lake Nakuru, Soysambu Conservancy and the Mau Forest Complex have not been asseesed by the IUCN, but are considered to be high priority fr conservancy by national conservation planning authorities
5: Key evolutionary processes	Environmental gradients	Connectivi	See default approach description in text	East to West/Plateau-Escarpment-Lowland gradent		Yes		The variation in altitude caused by the location of the study area on the plateau above the escarpment allows for the establishment of an ecotone.	No	While habitat connectivity is present, the transformation of the landscape of the Nairobi-Nakuru-Mau Summit region weakens this connectivity significantly
		Environmental gradient	See default approach description in text	East to West/Plateau-Escarpment-Lowland gradent		Yes		Through the SBSA two ectones highlighted between the high altitude afromontane rainforests at 2,500m and the lowland rift valley at 1,900m	Yes	Strong environmental gradients are present in the Nairobi-Nakuru-Mau Summit region based on vast altitudinal change

3.1.4.3 Criteria 2

This is a direct listing for species that have a restricted range and with likely presence in the study area that should be considered at this stage. Based on the 2019 revision of the IFC PS6 guidance notes, the only avifaunal species encountered and listed in the baseline reports with an estimated extent of occurrence (EOO) small enough to qualify under the criteria is the Kikuyu white eye (*Zosterops kikuyuensis*) which has an EOO of 28,200km^2. This species was commonly sighted in the study area during the field surveys, particularly in forested and upper woodland habitats in the far east of the study area. While it is likely that at least 10 reproductive units were present in the study area, based on the size of the species' distribution and its classification as 'Least Concern' by the IUCN's Red List it can be considered unlikely that the study area regularly holds at least 10% of the global population of this species and therefore the criteria is not met.

Within the herpetofaunal category eight species recorded (or expected to occur) in the AoA had EOOs low enough to consider meeting criteria. They are; the Kenya River Frog (*Phrynobatrachus keniensis*) with an EOO of 19,000km^2, the Mountain Reed Frog (*Hyperolius montanus*) with an EOO of 15,000km^2, the Lönnbergs Toad (*Mertensophryne lonnbergi*) with an EOO of 16,455km^2, the Tigoni Reed Frog (*Hyperolius cystocandicans*) with an EOO of 24,409km^2, the Kinangop River Frog (*Phrynobatrachus kinangopensis*) with an EOO of 16,569km^2, the Jackson's Three-horned Chameleon (*Trioceros jacksonii*) with an EOO of 30,400km^2 and the Kenya Horned Viper (*Bitis worthingtoni*) with an EOO of between 10,823 and 15,619km^2. It is highly likely that the Nairobi-Nakuru-Mau Summit CH AoA holds at least 10 reproductive units of all the species listed above. However, based on the range distributions and IUCN threatened status of these species it is believed to be unlikely that the CH AoA holds 10% of the global population of any of these species and therefore the criteria is not met. The Mocquards Toad (*Mertensophryne mocquardi*) is also considered range restricted, however based on a lack of data regarding this species there is no accepted EOO and thus the species cannot be considered to qualify under the criteria.

Within the freshwater macroinvertebrate category only one species recorded in the AoA had an EOO low enough to consider meeting the criteria. This was *Bulinus permembranaceus*, which has an EOO of 3000km^2. Based on expert opinion it is believed that the CH AoA does not hold at least 10% of the global population of this species and therefore does not meet the criteria.

3.1.4.4 Criteria 3

While a range of migratory species are listed, it is extremely unlikely that ≥ 1 percent of the global population for the species may reside or be present in the CH AoA at any point of the lifecycle of the species. It is equally unlikely that the Nairobi-Nakuru-Mau Summit CH AoA would predictably support ≥10 percent of the global population of any of the species during periods of environmental stress. The majority of migrant species were listed as 'Least Concern' by the IUCN's red list, indicating that populations are sufficiently large to further support the notion that it is unlikely that ≥10 percent of the global population would be dependent on the study area. The criteria is therefore not considered as met.

3.1.4.5 Criteria 4

To date there is no Kenyan ecosystem listed on the IUCN's red list of ecosystems. However, the Kenya Wildlife Service (2021) has listed Lake Elementaita, Marula Estates, Lake Nakuru, Soysambu Conservancy and the Mau Forest Complex as endangered ecosystems. There is no data available to indicate the Kenya Wildlife Service's methodology behind this endangered ecosystem selection. However, the majority of these sites are also considered as KBAs and thus while satisfying the determination of critical habitat for criteria 4, the designation of these sites as critical is also supported through a number of different routes.

3.1.4.6 Criteria 5

While there are no supporting texts to justify classifying any part of the project area of interest as critical habitat directly under this criterion, west of the study area lies an escarpment zone which creates a transition in the landscape from upland, high moisture, Afromontane areas with altitudes of up to 2,500m, to lowland areas with regular drought regimes with altitudes of up to 1,900m. The majority of the study area is located in the upland high moisture area however this topography creates two ecotones between the different ecological systems. This meets the 'environmental gradient' key evolutionary process and the 'connectivity' key evolutionary process. The former is considered important for genetic diversity maintenance and speciation in the study area. However, the latter is considered to be somewhat weak in the Nairobi-Nakuru-Mau Summit landscape based on its fragmented nature which limits the migratory capacity of many species.

Based on the standardised sensitivity analysis undertaken using baseline data, and the standardised sensitivity analysis undertaken using scoping data (Gaugris, 2021), the following areas appear as particularly important drivers of biodiversity sensitivity, and may be considered as drivers for evolutionary processes:

- Lake Nakuru National Park – for which almost 49% of the area is flagged as high sensitivity (sensitivity class 4).
- Soysambu Conservancy – for which 86% of the area is flagged as high sensitivity (sensitivity class 4)

The following vegetation types were consistently flagged as high sensitivity (high proportion of area in sensitivity class 4):

- Afromontane rainforest,
- Water bodies,
- Riverine wooded vegetation,
- Edaphic grasslands on drainage-impeded, seasonally flooded soil or freshwater swamp.

The following land use classes were consistently flagged as high sensitivity (high proportion of area in sensitivity class 4):

- Closed woodlands and forests,
- Water,
- Wetlands.

Areas which are located between 1,200m and 3,500m away from roads were also consistently flagged as high sensitivity (class 4). Furthermore, areas located between 1,500 and 1,800m altitude were flagged as high sensitivity (class 4). Generally flat land was also classed as high sensitivity (class 4). Aquatic and seasonal or permanent wetlands were flagged as sensitivity class 4, with many riverine areas classed as very high sensitivity (class 5). The majority of land covered by canyons and deeply incised streams, alongside mid-slope drainages and shallow valleys were flagged as sensitivity class 5 or 4.

This sensitivity analysis shows that a large proportion of the land is already transformed and has particularly low sensitivity. However flat and south facing areas which contain forests, waterbodies, riverine systems or wetlands are of particular importance for biodiversity in the landscape. Further to this, sites which are situated at least 1,200m away from roads and at altitudes of anywhere between 1,500 and

1,800m are also of importance. Steams and drainage lines have been shown to be particularly sensitive and may well act as corridors for wildlife and maintain connectivity in this heavily fragmented landscape (Appendix 1, Figure D).

PS6 § GN54 (2019 version). Projects that are located within internationally and/or nationally recognised areas of high biodiversity value may require a critical habitat assessment. Examples include the following:

- *Areas that meet the criteria of the IUCN's Protected Area Management Categories Ia, Ib and II.*
- *Key Biodiversity Areas (KBAs) which encompass Important Bird and Biodiversity Areas (IBAs).*

PS6 § GN55 (2019 version). Based on the mitigation and management requirements of paragraph 17 of Performance Standard 6, some areas will not be acceptable for financing, with the possible exception of projects specifically designed to contribute to the conservation of the area. Consultation with the relevant national and international organisations that designate these areas is required. These areas should be identified during the assessment of critical habitat and brought to the attention of the IFC as early as possible in the financing process. They include the following:

- *UNESCO Natural and Mixed World Heritage Sites*
- *Sites that fit the designation criteria of the Alliance for Zero Extinction (AZE).*

3.1.4.7 Areas that meet the criteria of the IUCN's Protected Area Management Categories Ia, Ib and II.

A review of IUCN protected area categories highlights no specific category 1a or 1b protected areas in the project AoA. However, there are 32 category II protected areas in Kenya, with four in close proximity of the project. Hell's Gate National Park, Lake Nakuru National Park and Mount Longonot National Park are all located within the project's AoA and would both be considered as critical habitat. Aberdare National Park is located just outside of the project's AoA, however it is located within the project's RAA and based on its high biodiversity value can be considered as critical habitat (Appendix 1, Figure E).

3.1.4.8 Key Biodiversity Areas (KBAs), which encompass inter alia Ramsar Sites, Important Bird and Biodiversity Areas (IBAs), Important Plant Areas (IPAs).

There are multiple KBAs within the study area all of which can be considered as critical habitat (Appendix 1, Figure F). There are three Ramsar sites; Lake Nakuru (Site 476), Lake Elementaita (Site 1498) and Lake Naivasha (Site 724). All are located in the project's AoA. There are five Important Bird Areas (IBAs) located in the project's regional assessment area; Kikuyu Escarpment Forest, Kinangop Grasslands, Lake Naivasha, Lake Elementaita and Lake Nakuru. There are a further three IBAs within the project's RAA; the Mau Forest Complex, Mau Narok-Molo grasslands and the Aberdare Mountains. No Important Plant Areas have been identified in Kenya as of yet.

3.1.4.9 UNESCO Natural and Mixed World Heritage Sites

There are seven World Heritage Sites in Kenya, of which three are Natural World Heritage Sites. The only site to be within the project's AoA is the Kenya Lake System in the Great Rift Valley. This World Heritage Site incorporates Lake Elementaita and Lake Nakuru, both of which are within the study area's regional assessment area and both of which should be considered as critical habitat. The lake system is considered a World Heritage Site as it incorporates Criterion vii (presenting exceptional ranges of geological and biological processes of exceptional beauty), Criterion ix (illustrating ongoing ecological and biological processes) and Criterion x (being the single most important foraging site for the Lesser Flamingo (*Phoeniconaias minor*) in the world) (Appendix 1, Figure G).

3.1.4.10 Sites that fit the designation criteria of the Alliance for Zero Extinction (AZE)

No Alliance for Zero Extinction sites are located in the project RAA. The closest Alliance for Zero Extinction (AZE) site to the project's RAA is Mount Kenya, which is located at least 90km away from the planned road upgrade site.

4 IFC PS6 Habitat Classification – Map

A map summarising the observations in the previous section is provided to highlight the key areas for the project. Figure 4 provides an overview of the modified, natural and critical habitat features discussed. The map must be considered as a summary of the modified, natural and critical habitat zones for the project AoA and the project area of interest contained within.

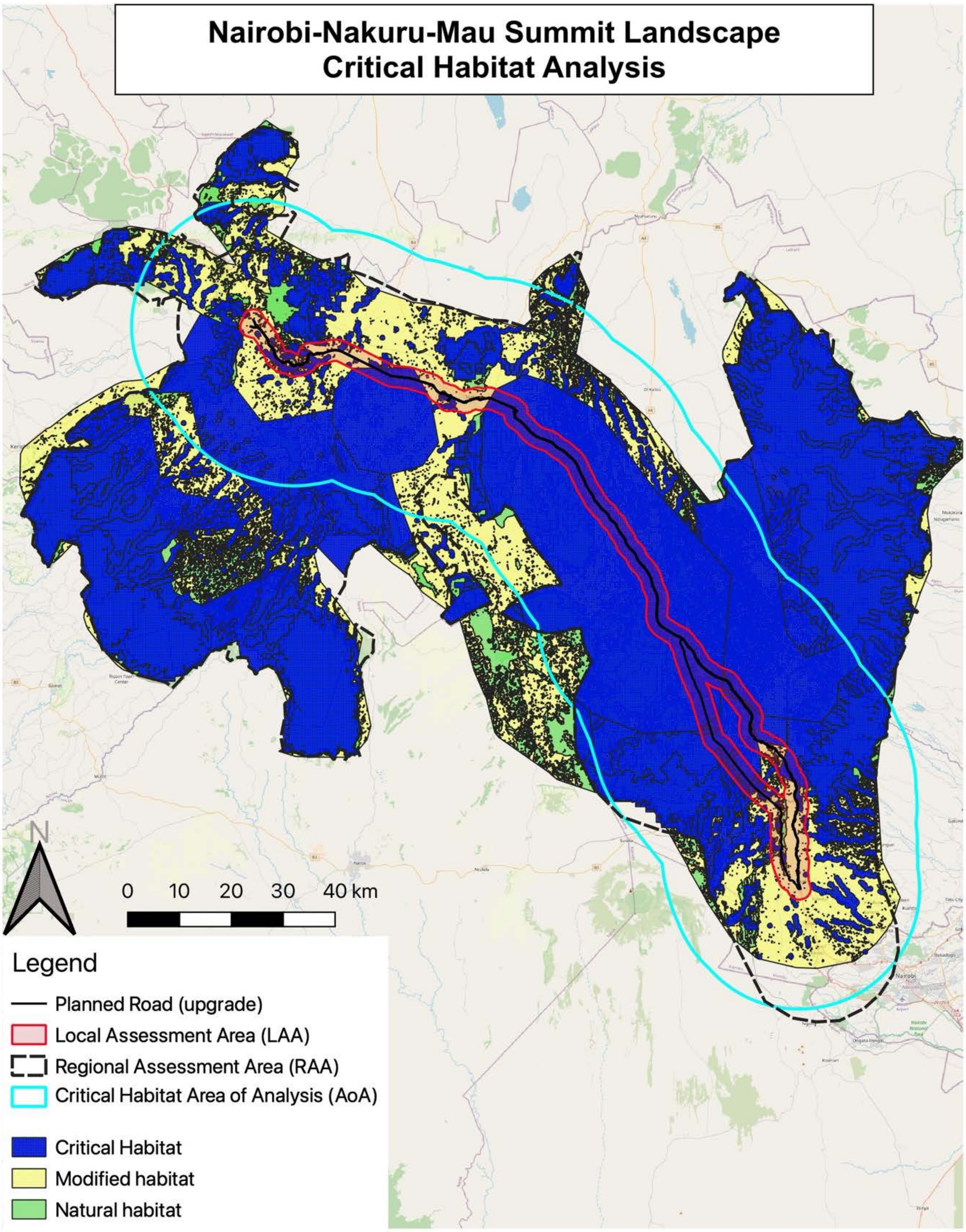


Figure 4: Representation of habitat classification in the Nairobi-Nakuru-Mau Summit study area as per IFC PS6 guidelines.

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6 APPENDIX 1

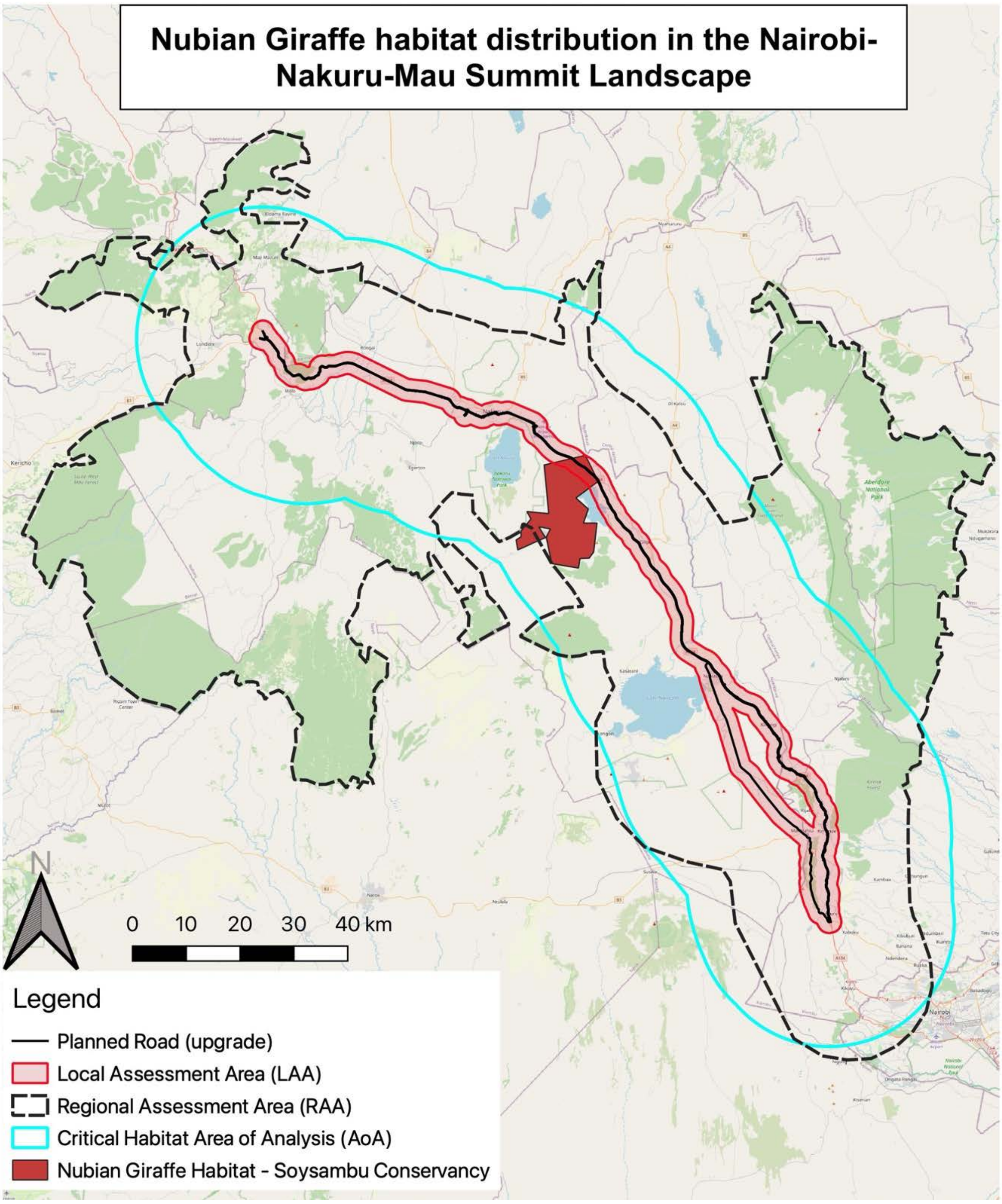

Figure A: Nubian giraffe (*Giraffa camelopardalis camelopardalis*) distribution across the Nairobi-Nakuru-Mau Summit study area

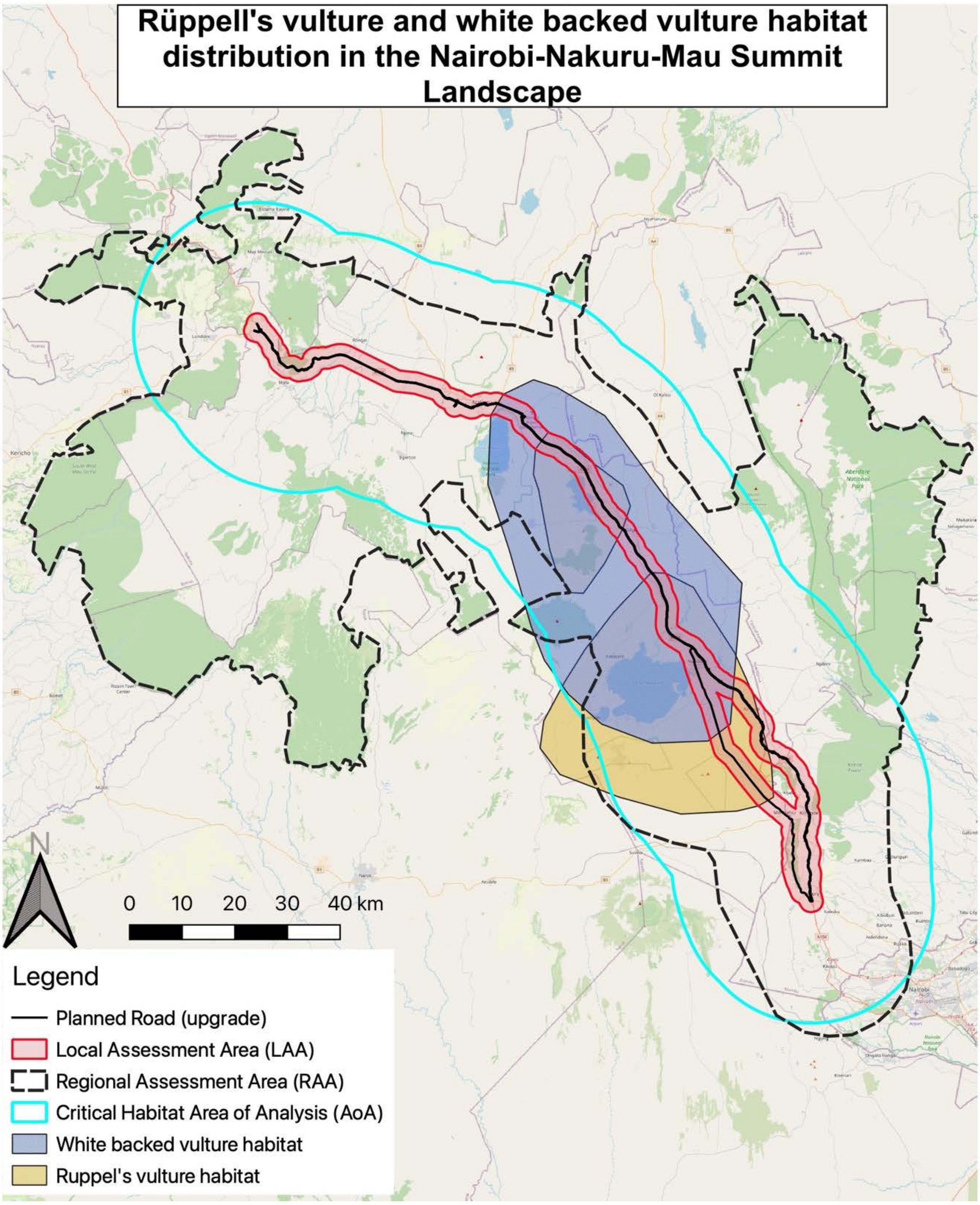

Figure B: Rüppell's vulture (*Gyps rueppelli*) and white-backed vulture (*Gyps africanus*) distribution across the Nairobi-Nakuru-Mau Summit study area

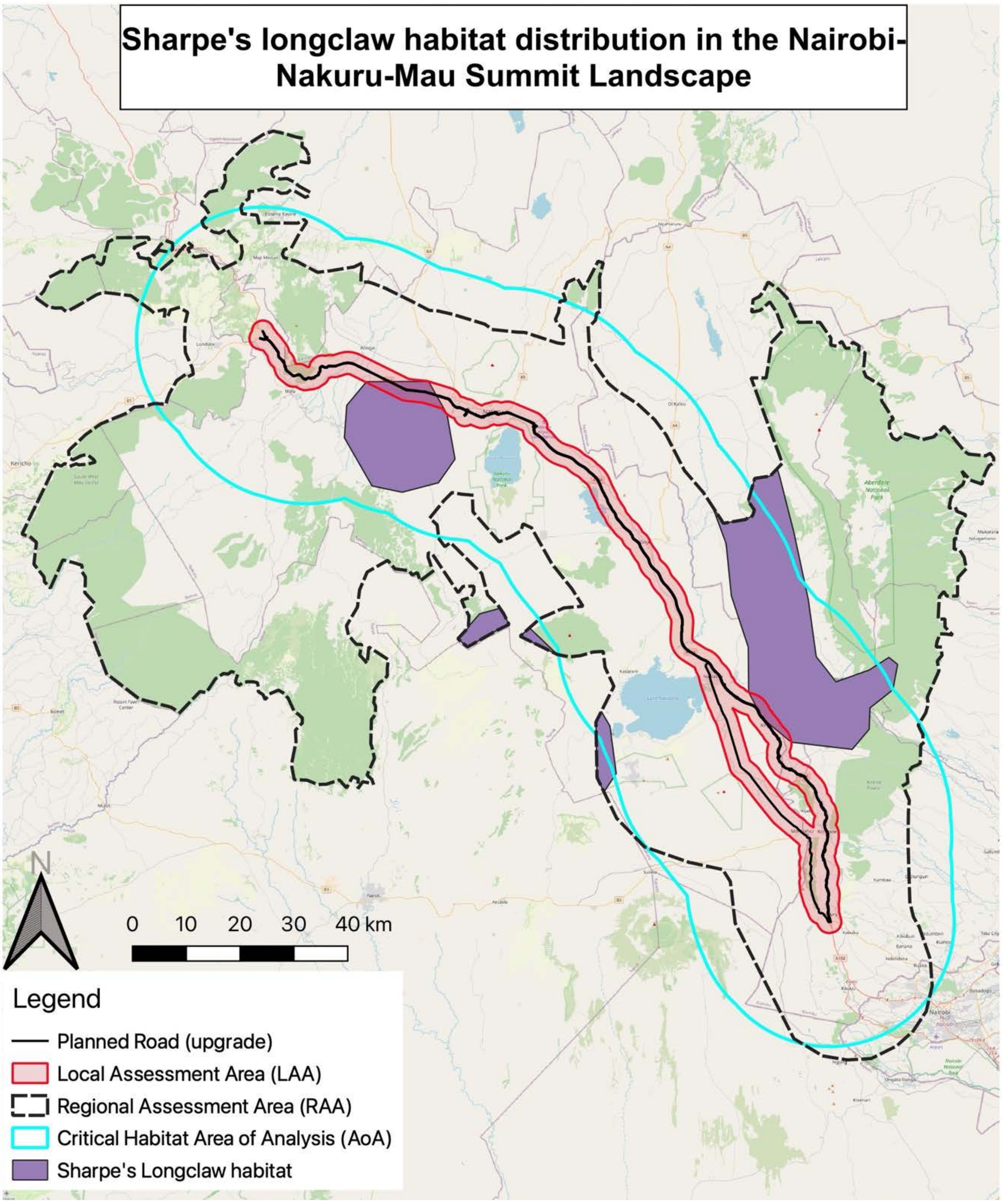

Figure C: Sharpe's Longclaw (*Macronyx sharpei*) distribution across the Nairobi-Nakuru-Mau Summit study area

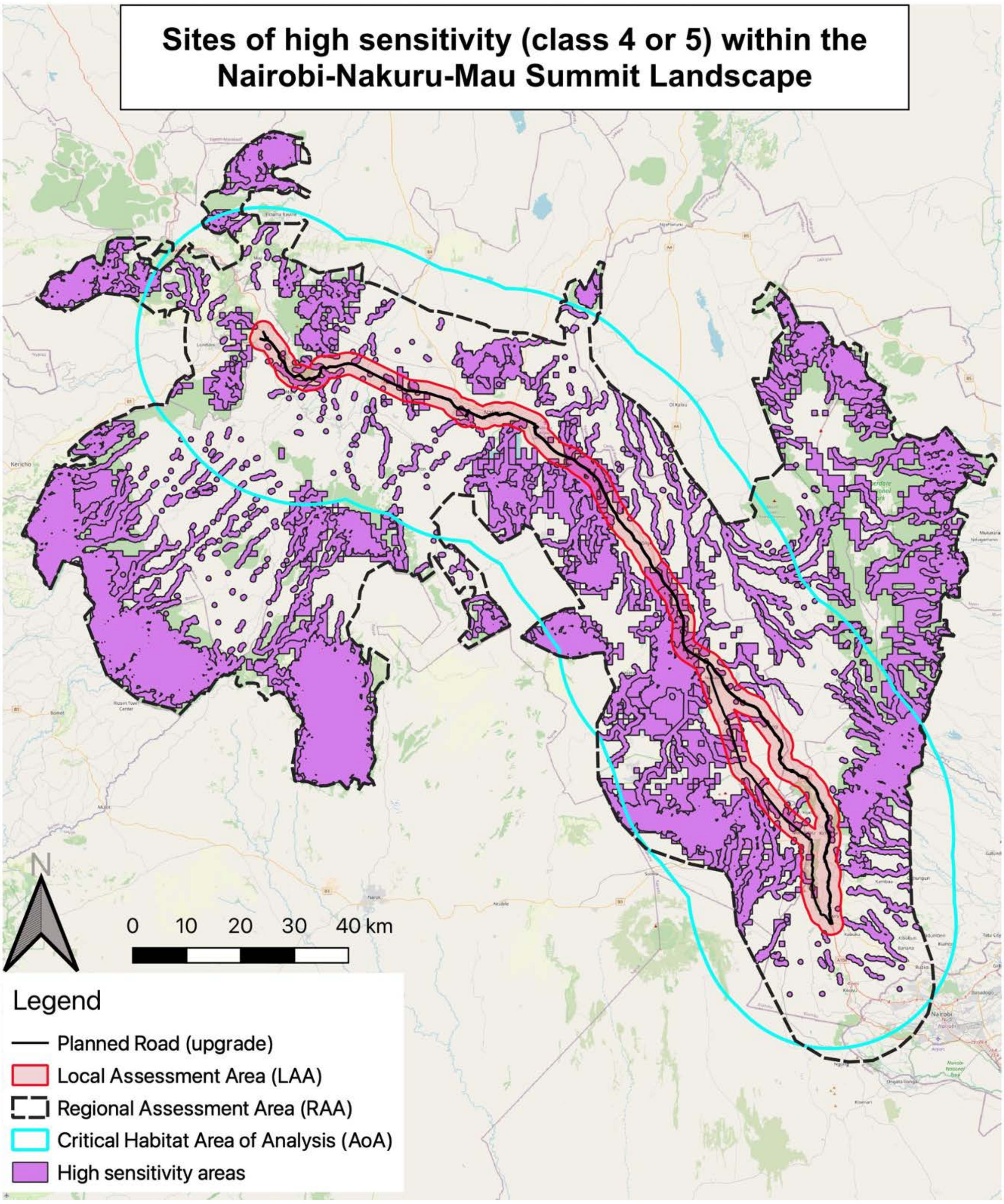

Figure D: Location of sites which were flagged as high sensitivity (class 5 buffered by 400 m to ensure the consideration of edge effect minimisation) in the SBSA extrapolated to the RAA. No data was available within section of the CH AoA and cannot be represented here.

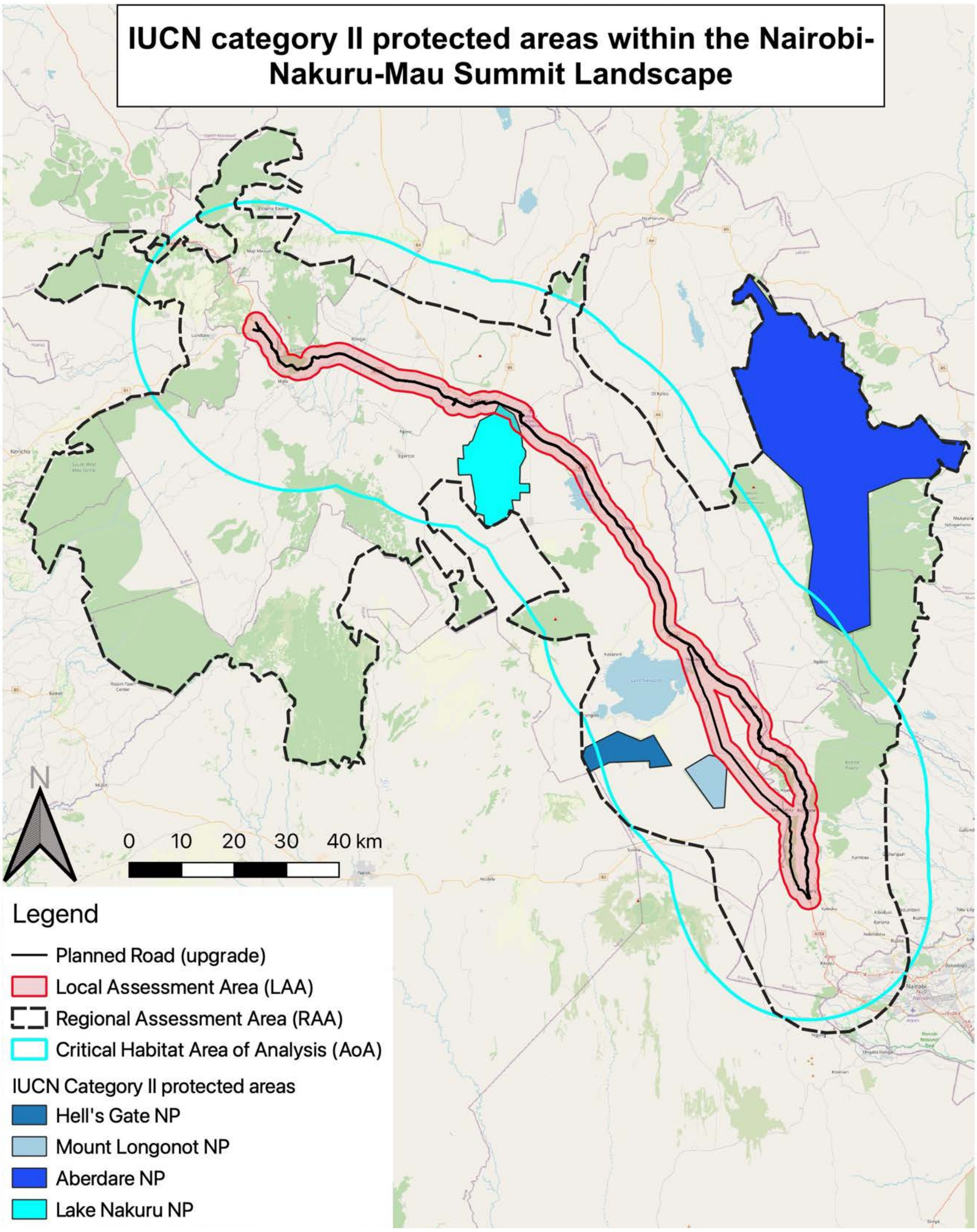

Figure E: Category II protected areas as classified by the IUCN in the Nairobi-Nakuru-Mau Summit study area

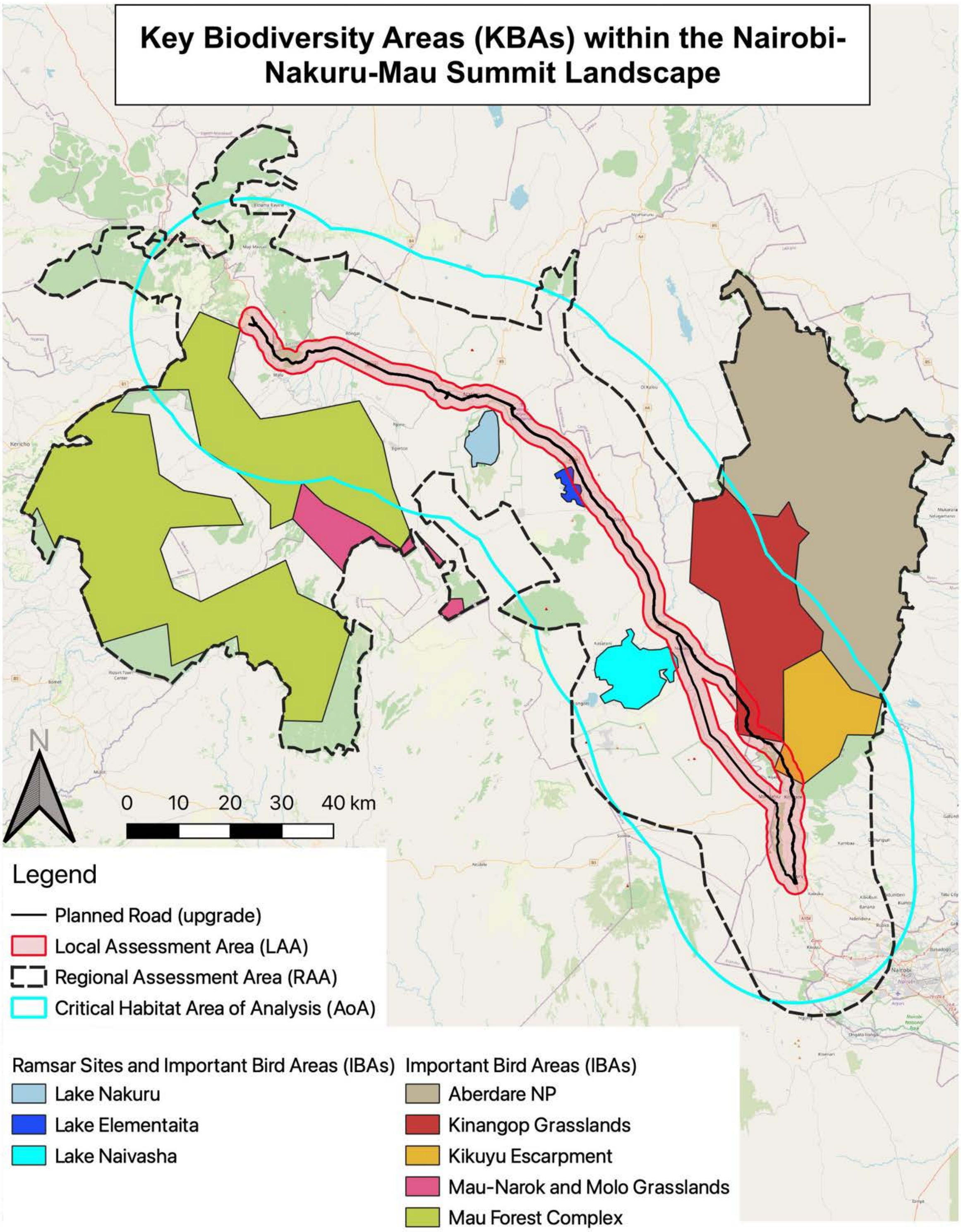

Figure F: Key Biodiversity Areas (including Important Bird Areas (IBAs) and RAMSAR sites) across the Nairobi-Nakuru-Mau Summit study area

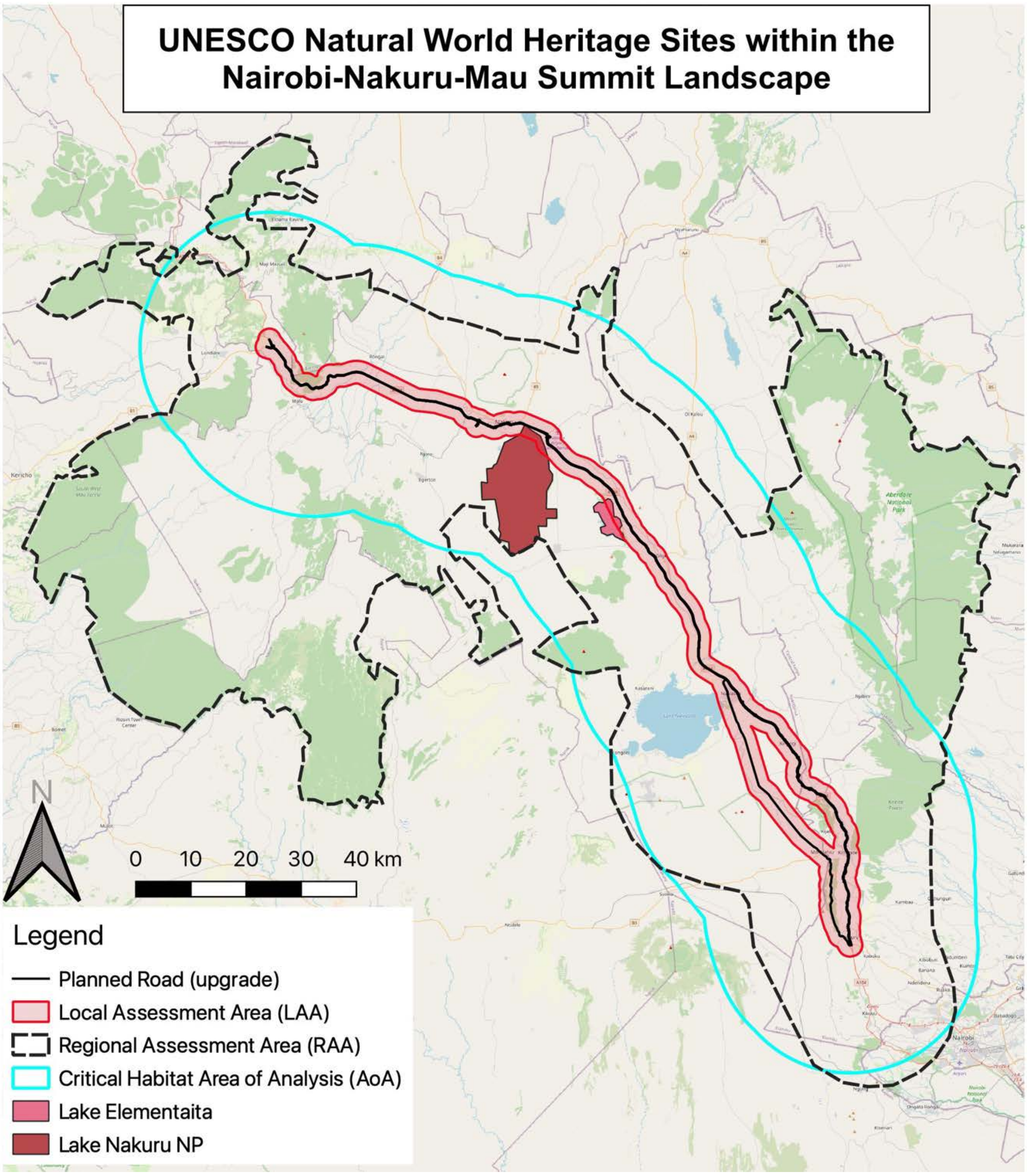

Figure G: UNESCO Natural World Heritage Sites in the Nairobi-Nakuru-Mau Summit study area

APPENDIX

6-24 ECOSYSTEM SERVICES BASELINE

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NAIROBI-NAKURU-MAU SUMMIT HIGHWAY PROJECT

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

ECOSYSTEM SERVICES BASELINE REPORT

WSP REF.: 201-10312-00

DATE : 2 AUGUST 2021

CONFIDENTIAL

MERIDIAM S.A.S., VINCI CONSTRUCTION S.A.S., VINCI CONCESSIONS S.A.S.

NAIROBI-NAKURU-MAU SUMMIT HIGHWAY PROJECT

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

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PRELIMINARY REPORT

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1 INTRODUCTION

As part of the Environmental and Social Impact Assessment (ESIA) for the Nairobi-Nakuru-Mau Summit Highway, comprehensive environmental and social baseline studies have been conducted. The current report presents the results of the ecosystem services baseline studies. These studies have been conducted in compliance with international best practices, namely IFC's Performance Standards (PS). The objectives, methodology and results are presented in the following sections.

1.1 DEFINITION OF ECOSYSTEM SERVICES AND OBJECTIVE OF THE ECOSYSTEM SERVICES ANALYSIS

An ecosystem is defined as a dynamic complex of plants, animals, micro-organisms and non-living components interacting as a functional unit (MEA, 2005). Human communities are an integral part of ecosystems and are beneficiaries of many goods and services they provide. These benefits are recognised as Ecosystem Services (ES).

The concept of ES has grown in importance over the last decade, particularly following the Millennium Ecosystem Assessment (MEA). The definition of this concept comes from the evaluation report, which states that such services are the benefits people obtain from ecosystems (MEA, 2005; IFC, 2019). ES could be considered as the direct and indirect contributions of ecosystems to human well-being (Kumar, 2010).

ES are grouped into four categories that have been studied:

- Supply services: which refer directly to products people obtain from ecosystems (e.g., agricultural products, plants to eat, game, medicinal plants, fresh water, biofuel, timber, etc.);
- Regulating services: which are the benefits humans obtain from the regulation of ecosystem processes (e.g., climate regulation, waste decomposition, purification of water and air, etc.);
- Cultural services: which refer to the non-material benefits people obtain from ecosystems (e.g., sacred and spiritual sites, ecotourism, education, etc.);
- Supporting services: which are the natural processes that maintain the other services (e.g., nutrient cycling, genetic production and genetic exchange channels, etc.).

ES are divided into two types according to IFC's PS 6:

- Type I: Provisioning, regulating, cultural and supporting ecosystem services, over which the promoter (RVH) has direct management control or significant influence, and where impacts on such services may adversely affect communities.
- Type II: Provisioning, regulating, cultural and supporting ecosystem services, over which the promoter (RVH) has direct management control or significant influence, and on which the project directly depends for its operations.

The objective of the Ecosystem Services Analysis is to identify ES provided within the Project's Regional Assessment Area (RAA), and to determine the Priority Ecosystem Services (PES) as prescribed in IFC's PS6.

The PES are classified into two categories according to specific circumstances (IFC, 2019):

Type I ES will be considered priority, under the following circumstances:

- Project operations are likely to result in a significant impact on the ES;
- The impact will result in a direct adverse impact on affected communities' livelihood, health, safety and/or cultural heritage; and
- The project has direct management control or significant influence over the ES.

Type II ES will be considered priority under the following circumstances:

- The project directly depends on the ES for its primary operations; and,
- The project has direct management control or significant influence over the ES.

The PES identified will then be considered as part of the impact assessment conducted by WSP and specific mitigation measures will be proposed.

1.2 GENERAL CONTEXT OF ECOSYSTEM SERVICES AND ROADS

Roads are a cornerstone of economic development. The connectivity and access made possible by roads provide vital benefits to people but can also have negative feedback on ecosystem services. A number of ecosystem services are particularly important to road projects. Roads either depend on these services to reduce risk from natural hazards and rates of deterioration, or they can reduce the benefits these services provide to people.

The consideration of ecosystem services into road project design and development can lead to more sustainable, cost-effective roads while maintaining or enhancing the additional benefits nature provides to the region's citizens, from clean water and air, to food and timber (Mandle et *al.*, 2016). Ecosystem services that are important to road projects include flood regulation, erosion control, landside prevention, water quality regulation, air quality regulation and carbon sequestration and storage for climate regulation.

Vegetation from various habitats reduces peak storm flows and flood height by enhancing soil infiltration and increasing water storage, reducing storm runoff and risks of road flooding. It can also reduce the amount of sediment in runoff and storm water reaching the roadway, which can reduce the impact of sediment scour to roads and bridges, lowering infrastructure and vehicle maintenance costs. Moreover, vegetation will help to stabilize soils and hillsides, contributing to the prevention of landslides in risk-prone areas. This in turn can result in reduced safety concerns for road users, reduced maintenance costs, and enhanced road use reliability.

On the other hand, exposed roadsides and unpaved roads are often sources of sediment themselves. Roads can also facilitate the conversion of natural vegetation to other land use types that are less effective at retaining sediment, such as agricultural fields or adjacent paved areas.

Roads, and especially the traffic they generate, reduce air quality and can lead to an increase in carbon dioxide and other greenhouse gases in the atmosphere. Vegetation can help to mitigate impacts of roads on air quality by trapping and filtering pollutants and can also offset carbon emissions associated with road construction or increased road traffic.

Erosion control, water quality regulation, flood regulation, and climate regulation are some of the ecosystem services commonly lost with road development. However, the greatest impact roads have on natural capital often come from their indirect effects, such as the conversion of areas along roads from natural vegetation to agricultural production. By increasing access and reducing transportation costs, roads spur changes in local land use such as increasing timber harvests and conversion of forests to pasture or cropland. New or improved roads can also lead to changes in land management practices by allowing for easier and cheaper access year-round. Some of the indirect impacts of roads are in fact economic benefits, providing jobs and important material goods. However, there is also a risk that the increased access to natural resources provided by roads can lead to degradation and depletion of these ecosystem goods and services (Mandle et al., 2016).

In contrast, the barrier effect created by road can decrease the ease of access to a given resource locally. Without adequate crossing structures, the road can potentially block or make access difficult by local communities to water, forest, agricultural land, grazing resources, etc. on the other side of the road.

2 METHODOLOGY

The ES analysis is based on various information coming from the baseline characterisation of different physical, biological and social components and on literature review. In order to obtain more information and to properly characterise the PES, specific consultations with local community representatives have been held. The PES identification process is then supported by the application of prioritization criteria.

2.1 CONSULTATIONS

Consultations on ecosystem services were conducted during meetings held with sub-counties/wards, community members and chiefs. They were organized as part of the second round of stakeholder consultations for the ESIA; the general objectives of the consultations on ecosystem services are, namely:

- Define the role of habitats in the well-being of communities and understand what resources and services, arising from these habitats, are present in the project area;
- Identify the natural resources and services resulting from the habitats in the project area for which the populations have the most concerns (e.g., reduced accessibility to certain areas for collecting plants or animals, punctual deterioration of water quality);
- Identify the components of the environment (specific habitats (wetlands, rivers, lakes, forests, savannas, etc.), seasons, types of soil, topography, etc.) that influence the availability of the resources used and the services that benefit local populations;
- Make a list of plants or animals consumed or harvested and identify their use;
- Identify and locate the habitats that are most important for the well-being of local populations;
- Provide insight on how the use of these resources could be affected by the highway (barrier to access, induced access, land conversation) to better mitigate these impacts.

Specific ES focus groups/mapping sessions were held with local community representatives, targeting natural resource users in each sub-county of the LAA, including women, elders, farmers, pastoralists, fishermen and natural resource traders (wood, charcoal, water, other). Meetings were led by WSP's biodiversity specialist and a national Research Scientist from the National Museums of Kenya's Center for Biodiversity.

Furthermore, some meetings were held with local traditional practitioners, as well as with fisheries representatives. Table 2-1 details the different meetings held, and Figure 2-1 contains photos from some of these meetings. The attendance sheets for each ES focus group are provided in Appendix 7-X of the ESIA.

Moreover, ecosystem services were also discussed during meetings with VMG representatives. In particular, questions on ecosystem services were asked during meetings with Maasai Women Representatives in Maai Mahiu, with Ogiek representatives in Eburru, and Mariashoni.

Table 2-1 Groups consulted for ecosystem services characterisation

Dates	Meeting	Nb of participants
May 24, 2021	Limuru Sub County Community Meeting	12
May 25, 2021	Lari Sub County Community Meeting	13
	Traditional practioner: Herborist shop, Kimende	3
May 26, 2021	Naivasha Sub County Community Meeting (South)	14
	Maasai traditional practitioners	4
May 27, 2021	Kinangop Sub county Community Meeting	16
	Fisheries Representative: Karagita Beach Management Unit (BMU)	3
May 28, 2021	Kuresoi North Sub County Community Meeting	11
May 31, 2021	Rongai Sub County Community Meeting	11
June 2, 2021	Molo and Koibatek Sub Counties Community Meeting	20
June 3, 2021	Gilgil Sub County Community Meeting	11
June 4, 2021	Nakuru East and Nakuru West Sub Counties Community Meeting	9
June 7, 2021	Naivasha Sub County Community Meeting (North)	10

a) Mapping Session in Molo and Koibatek sub county

b) Meeting with Maasai Traditional Practitioners in Maai Mahiu

c) Meeting with Karagita BMU Representative

d) Herborist shop, Kimende

Figure 2-1 Photos of some meetings held to gather information on ecosystem services in the RAA

2.2 IDENTIFICATION OF PRIORITY ECOSYSTEM SERVICES

The identification of PES is based on the following prioritization criteria (Table 2-2):

- Level of dependence on the ES - for affected communities and their well-being (Type I) or for Project performance (Type II);
- Interaction with drivers of change on ES (Type I) or with Project operations (Type II);
- Replaceability / Management potential - accessibility and efficiency of a possible alternative to the affected ES.

Table 2-2 ES prioritization criteria

Level of Dependence on the ES - for affected communities and their well-being (Type I) or for Project performance (Type II)	
Low	A few communities are beneficiaries for this given ES or this ES contributes slightly to their well-being (Type I) or the Project depends slightly on ES and its performance is slightly affected by the loss. The intensity of use and the degree of dependence are low.
Medium	Benefit from the ES is important among local communities or generalised for given groups (Type I) or the ES loss could affect Project performance without compromising it (Type II). Intensities of benefit and degrees of dependence are variable.
High	Widespread or significant benefit for local communities and ES is of major importance for them (Type I). Project performance is considerably reduced by the ES loss (Type II). Benefit is high and degree of dependence is major.
Interaction with drivers of change on ES (Type I) or with Project operations (Type II)	
Low	The ES can slightly be impacted without changing significantly its availability for beneficiaries or for Project performance. The disturbance can be within the normal range of natural variations.
Medium	The ES can be altered at a point where the availability for beneficiaries or for Project performance can be reduced. However, the impact does not threaten the long-term viability of the ecosystem which provides the ES.
High	The ES can be lost, or a significant proportion of its availability could be reduced for beneficiaries or for Project performance. The long-term viability of the ecosystem which provides the ES is threatened.
Replaceability/Management potential - Accessibility and Efficiency of possible alternative to the ES affected	
Low	Highly specific ES, with no alternatives easily accessible or effective.
Medium	Some alternatives exist even if they are less favourable. Beneficiaries can access to the ES considering their capacity to pay or to find an effective alternative.
High	Many accessible and effective alternatives for beneficiaries.

The first step of the PES identification process is the description of the level of dependence and replaceability of ES provided inside the study area. With the use of a matrix (Table 2-3), it is then possible to identify the ES that are more prone to be identified as a PES. When the replaceability of an ES is high, it cannot be a PES.

Drivers of change on ES are identified by the analysis of anticipated impacts on physical, biological and social components related to Project activities. They notably comprise the following:

- Direct loss and fragmentation of natural or modified habitats;
- Degradation and disturbance of natural or modified habitats (modification to on-site hydrology, degradation of water quality, introduction of invasive species);

- Reduction in the availability and quality of resources due to demographic and economic changes related to induced access and the influx of people seeking socio-economic opportunities;
- Reduction in accessibility because of road barrier effect.

Direct loss and fragmentation of natural or modified habitat caused by the project will be very low, the majority of works and infrastructure remaining within the existing road right-of-way.

Table 2-3 Determination matrix for assessment of ES

LEVEL OF DEPENDANCE	INTERACTION PROJECT DRIVERS OF CHANGE OR OPERATIONS	REPLACEABILITY	PRIORITY ECOSYSTEM SERVICE
Low	Low	Low	Not PES
		Medium	Not PES
		High	Not PES
	Medium	Low	Not PES
		Medium	Not PES
		High	Not PES
	High	Low	PES
		Medium	Not PES
		High	Not PES
Medium	Low	Low	Not PES
		Medium	Not PES
		High	Not PES
	Medium	Low	PES
		Medium	Not PES
		High	Not PES
	High	Low	PES
		Medium	PES
		High	Not PES
High	Low	Low	Not PES
		Medium	Not PES
		High	Not PES
	Medium	Low	PES
		Medium	PES
		High	Not PES
	High	Low	PES
		Medium	PES
		High	Not PES

3 RESULTS

A list of ES provided inside the RAA has been developed based on a literature review on ES, the natural and modified habitats identified within the RAA, and the consultations held with the communities crossed by the Nairobi-Nakuru-Mau Summit Highway (Table 3-1). Natural and modified habitats have multiple vocations associated with a range of uses by local communities:

- Provisioning ES are mainly associated with specific species found inside the RAA;
- Cultural ES are mainly associated with specific habitats inside the RAA, notably for tourism;
- Regulation and support ES are related to interaction between biophysical and social components at a wider scale;
- Due to their complexity and overarching quality, support ES have not been specifically assessed inside the RAA but are known to contribute to all types of ES.

Table 3-1 ES provided inside the LSA

Ecosystem services	Definition
Provisioning services	
Agricultural potential and production	Areas with agricultural potential, including all crops and agricultural products grown by local communities for human and livestock consumption.
Livestock and forage resources	Forage resources, water and others supporting livestock and animals owned for consumption, domestic or commercial uses.
Fishing and fisheries resources	Fishing stock caught or aquaculture within the water streams inside in the Tchivouba sub-catchment and Loémé River.
Hunting and bush meat	Animal species trapped or hunted for consumption, including insects, mammals, birds, amphibians and reptiles.
Wild food products	Products collected in the wild for food, other than animal proteins (vegetal products, mushrooms or honey).
Traditional medicine	Mineral, plant or animal used in order to maintain people’s health as well as to prevent, diagnose, treat or care for physical and mental diseases.
Building. carpentry and craft materials	Mineral or vegetal material (ligneous or non-ligneous) used for construction purposes, to construct furniture and to make craft objects.
Biofuel	Animal or vegetal products used as energy sources.
Water resources	Groundwater and surface water used as tap water or for domestic, commercial or agricultural means. Comprises all the natural processes that regulate its quality or quantity.
Regulation services	
Air quality control	Ecosystems influence in terms of gases exchange or filtration of physical or chemical particles in the air (ex : dust, O_2 CO2).
Climate regulation	**Global :** Ecosystems influence the absorption or emission of green gases and in the regulation of air masses.
	Regional and local : Ecosystems influence on regional and local temperatures, rainfalls or on other climatic parameters.
Water regulation and erosion control	Ecosystems influence on the amplitude and period of water flow, water storage, aquifer filling and flood prevention. They also have a role of ecosystems in preventing erosion by retaining soil by intercepting rainfall, reducing the speed of runoff, etc.
Diseases and pest control	Influence of ecosystems on the dispersion and abundance of some diseases and pests.
Pollination	Role of ecosystems in the pollination of crops, cultivated trees and wild trees and plants. Animals (insects, birds, mammals, etc.) of surrounding habitats come to pollinate crops and other flowering plants.

Ecosystem services	Definition
Regulation of natural risks	Ecosystem capacity to reduce the damage caused by natural disasters and limit the frequencies and intensities of fire.
Cultural Services	
Sacred components	Cultural or religious value that population attaches to an ecosystem, a place or a species.
Recreation and Tourism	Nature, particularly protected areas and wildlife plays an important role in supporting tourism. Ecosystems and biodiversity are therefore an important source of employment and income generation.
Support Services	
Primary production	Production of organic matter by plants through photosynthesis and nutrient input. It forms the basis of the food chain.
Nutrients cycle	Nutrients cycle in the ecosystems (phosphorus, nitrogen, carbon, sulfur, etc.).
Habitat	Natural or modified areas which support flora and fauna communities.
Water cycle	Water transition through different receptors (atmosphere, terrestrial and aquatic habitats) in all its phases (solid, liquid and gaseous).

3.1 DESCRIPTION OF ECOSYSTEM SERVICES WITHIN THE LAA

The following sections present the description of ES for which an impact is anticipated from the Project's implementation. The description will allow a general understanding of the ES inside the RAA and definition of the PES according to the prioritization criteria and the determination matrix presented in the previous section.

3.1.1 PROVISIONING ECOSYSTEM SERVICES

3.1.1.1 AGRICULTURAL POTENTIAL AND PRODUCTION

Smallholder subsistence farmers make up some 80 percent of the active agricultural population and generate the most food in Kenya (UNEP, 2005). Many people in the project area live from the harvest of their agricultural activities. From information gathered during community meetings, about 27 different crops are cultivated in the sub-counties crossed by the proposed highway (Table 3-2). The distribution of these crops varies from one sub-county to another. Maize and cabbage are the two dominant crops along the highway, followed by potato and carrot, which also form important crops.

Most of these crops depend on rainfall through their growth stages. However, the ones grown in green houses are irrigated, such as pepper (capsicum), tomato, and flower plants. Crops irrigated in open fields are kale, cabbage and tomato.

The shamba system, a form of agroforestry, is practiced in the Kinale and Koibatek forests. In this system, the farmers are encouraged to cultivate primary crops (maize, beans) on previously clear-cut public forest land on the condition that they replant trees.

Most of the crops are grown for subsistence use and only sold when there is a surplus. Crops which are mostly grown for subsistence are maize and beans. In Maai Mahiu, Naivasha, Nakuru and Rongai sections, products are mostly sold in local markets. In Kuresoi and Molo/Koibatek sub-counties, most agricultural products are sold on the roadside. Marketing of agricultural products in Gilgil is a combination of both local market and roadside selling. In Kinangop and Lari, crops are sold along the road, in local markets and in distance markets such as in Nairobi. Residents in Limuru sell their crop produce locally and to markets in Nairobi. Products that have different marketing strategies are flowers, including pyrethrum, and wheat. Flowers are mostly exported overseas, and few are sold in Nairobi markets. Wheat is sold to middlemen or companies.

Agriculture forms the main economic activity among the residents along the proposed Highway. It is an activity both men and women practice, therefore, households rely on it for the better part of their income throughout the year.

This activity is marred with challenges that affect its full economic realization along the highway. According to community representatives, drought seems to affect crop production in all sections of the highway. Sub-counties that are particularly affected by drought are Mai Mahiu, Naivasha, Gilgil, Nakuru and Rongai. Another challenge that apparently affects most sections is flooding, poor market, poor roads, and high input cost.

Table 3-2 Agricultural crops cultivated in the RAA

Crop Most Frequently Mentioned	Crops Less Frequently Mentioned
Maize	Coriander
Cabbage	Pigeon Peas
Potato	Pepinos
Carrot	Coriander
Beans	Capsicum
Kales	Courgettes
Spinach	Broccoli
Tomato	Cauliflower
Onion	Pyrethrum
Flowers	Wheat
African Nightshade	Sorghum
Amaranthus	Grass
Spider Plant	Avocado
Snow Peas	

Table 3-3 Assessment of Agriculture Potential and Production Against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**High:** Most communities live mainly from the harvest of their agricultural activities.
Interaction with drivers of change on ES or with Project operations	**Medium:** Agriculture can be temporarily affected by changes to water quality during project construction. The project is expected to have an overall positive impact on hydrology by improving drainage infrastructure, which could reduce flooding of crops. Finally, the Project can indirectly affect agricultural activities by affecting the access to both sides of the road. Selling produce by the side of the road will also be affected.
Replaceability/Management Potential	**Low:** Agricultural land is widespread throughout the RAA. However, there might be increased demand for this land generated by the project.
Priority Ecosystem Services	**PES Type I**

3.1.1.2 LIVESTOCK AND FORAGE RESOURCES

Livestock largely sustains the livelihoods of the populations living along the Highway. Only the Ogiek community in Eburru does not keep livestock. Table 3-4 provides an overview of livestock activities in each sub-county crossed by the Highway. There are five common and distinct types of livestock reared by residents, starting with the more common ones: cattle, sheep, goats, followed by donkeys and pigs. Poultry is also present, especially chicken and ducks.

Livestock and poultry are mostly reared for economic income, and less for household food. Livestock product consumed daily in most households is milk, where excess is sold for income earning. Donkeys are handy in transportation of agricultural products and water and can therefore be used for earning income in some households through provision transportation of goods for individuals.

Livestock mostly graze on farms, roadsides and forests. Grazing in forests, however, requires a permit from the Kenya Forest Service (KFS) on an annual basis. Households living near the road and/or forest have easy access to the foraging resources than households far away from these locations. The average travel distance for livestock to foraging locations ranges between 1 – 5 km but can be more than 5 km in areas that experience severe drought incidences like Maai Mahiu and Gilgil areas.

The growing of forage resources is mostly linked to dairy cattle and goats. The common foraging resources developed in the Project area is napier grass; others include lucerne and oat. However, the development is not widespread along the project alignment. Some sub-counties do not grow feed resources, including Limuru, Lari, Mai Mahiu,

Water for drinking by livestock is found on farms, river/streams, springs, water pans and dams. On farm watering of livestock relies on piped water or boreholes which are hand dug. Livestock in areas such as Limuru and Lari have water mostly on farms hence livestock don't travel far in search for water. Forests such as Kuresoi and Kinale are important sources of water and forage for livestock especially during the dry season.

Livestock is especially important for Maasai communities, where it constitutes a social status symbol and a larger proportion goes to household consumption (about 30 %). The maasai community to the south of the A8 South (Namuncha village) herd their livestock in the Kikuyu Escarpment Forest along the A8 South and cross the road at different access points. This herding is practiced from February to July, travelling about 25 km 2-3 times a week. From August to January, there is a migration and the herdsmen will travel to Naivasha-Nakuru, Njoro- Mau Narok- Narok and back to Maai Maiu with caws.

Community representatives from Lari subcounty mentioned important road-crossing areas in Kinale, Kimende, Magina, Kariko and Nyambari (upland). In Gilgil, important crossing areas mentioned were Eastgate, Kambi Somali, Lake Elmentaita Lodge. In Nakuru, those areas were Pipeline, Mzee Wanyama area and Mbaruku area. No specific crossing areas for livestock were discussed in the other subcounties.

Bee keeping and honey harvesting is a very important activity for the Ogiek community living near Eburru. They still use the traditional log hives and are allowed to install them in the forest and access the forest for maintenance of the hives and harvesting of honey.

Table 3-4 Summary of livestock and forage resources per sub-county

Sub-county	Livestock Type	Reason for raring	Grazing Areas	Developed Resources	Watering area
Limuru	Pigs	Mostly for income	On farm	None	On farm
	Cattle	For milk used at household, for income generation	On farm, Forest	Growing of napier grass	On farm
	Donkey	Transportation of farm produce and water	On farm, roadside	None	On farm
	Goat	Mostly for income (through sale of milk)	On farm	None	On farm
	Sheep	Mostly for income through selling of wool.	On farm, roadside	None	On farm
Lari	Sheep	Mostly for income (sale for mutton)	On farm & roadside	None	On farm
	Cattle	Mostly for milk used by family & Income through sale of surplus milk	Mostly zero grazing	Napier grass	On farm
	Donkeys	Transport	On farm & roadside	None	On farm
	Bee	Income generation through sale of honey	Forest	None	N/A
Mai Mahiu	Cattle	Income generation through sale of meat, manures, and surplus milk	Roadside, on farm & rangeland	Napier grass, Rhodes grass, Oat, Millet, Lucerne	On farm & stream (Tongtong)
	Goat	Income generation through sale for meat	Roadside & rangeland	None	On farm & stream (Tongtong)
	Poultry	Family consumption & Income generation through sale for meat and eggs	On farm	Poultry feed normally purchased	On farm
	Bee	Income generation through sale for honey	Forest	N/A	N/A
Kinangop	Cattle	Income generation through sale of meat and surplus milk	Mostly on roadside. On farms and in the forest	None	Thiririka Dam, Shallow water pans
	Sheep	Income generation through sale of mutton and wool	Mostly on roadside. On farms and in the forest	None	Thiririka Dam, Shallow water pans
	Rabbit	Income generation through sale of meat	On farm	None	Thiririka Dam, Shallow water pans
	Pig	Income generation through sale of meat	On farm	None	Thiririka Dam, Shallow water pans
	Donkey	Income generation through transportation service	On farms & roadside	None	Thiririka Dam, Shallow water pans

Sub-county	Livestock Type	Reason for raring	Grazing Areas	Developed Resources	Watering area
Kuresoi	Cattle	Income generation through sale of meat and surplus milk	Roadside	Lucerne & Oat	Kuresoi forest
	Sheep	Income generation through sale of meat	Roadside	None	Kuresoi forest
	Donkey	Income generation through transportation service	Roadside	None	Kuresoi forest
Rongai	Cattle	Family consumption of milk & Income generation through sale of meat and surplus milk	On farms & roadside	Feeds are purchased	On farm
	Goat	Income generation through sale of meat	On farms & roadside	Feeds are purchased	On farm
	Sheep	Income generation through sale of meat	On farms & roadside	Feeds are purchased	On farm
	Poultry	Family consumption & Income generation through sale for meat and eggs	On farm	Feeds are purchased	On farm
	Pig	Income generation through sale of meat	On farm	Feeds are purchased	On farm
Molo/ Koibatek	Cattle	Family consumption of milk & Income generation through sale of meat and surplus milk	Roadside, Forest, on farm (tethering), Zero Grazing,	Napier grass, Feed purchased: hay, Unga Mill Feeds	Streams in Koibatek and Molo forests
	Poultry	Family consumption & Income generation through sale for meat and eggs	On farm	None	On farm
	Goat	Income generation through sale of meat	Roadside, Forest, on farm (tethering)	None	Streams in Koibatek and Molo forests
	Sheep	Income generation through sale of meat	Roadside, Forest, on farm (tethering)	None	Streams in Koibatek and Molo forests
	Pig	Income generation through sale of meat	On farm and purchased feed	None	On farm
	Rabbit	Income generation through sale of meat	On farm	None	On farm
	Donkey	Income generation through transportation service	Roadside, on farm (tethering)	None	On farm, Streams in Koibatek and Molo forests

Sub-county	Livestock Type	Reason for raring	Grazing Areas	Developed Resources	Watering area
Gilgil	Sheep	Income generation through sale of meat	Roadside, Around Lake Elementaita, Eburu Forest, Eastgate,	None	Springs in Diatomite area, Kariandusi stream, Ndimo farm
	Goat	Income generation through sale of meat	Roadside, Around Lake Elementaita, Eburu Forest, Eastgate,	None	Springs in Diatomite area, Kariandusi stream, Ndimo farm
	Cattle	Family consumption of milk & Income generation through sale of meat and surplus milk	Roadside, Around Lake Elementaita, Eburu Forest, Eastgate,	None	Springs in Diatomite area, Kariandusi stream, Ndimo farm
Naivasha	Cattle	Family consumption of milk & Income generation through sale of meat and surplus milk	Marura farm, Delamere farm, KWSTI, Roadside	Fodder is mostly bought for dairy cows	Lake Elementaita, River Karati
	Goat	Income generation through sale of meat	Marura farm, Delamere farm, KWSTI, Roadside	None	Lake Elementaita, River Karati
	Sheep	Income generation through sale of meat	Marura farm, Delamere farm, KWSTI, Roadside	None	Lake Elementaita, River Karati
	Poultry	Family consumption & Income generation through sale for meat and eggs	On farm	Feeds are purchased	On farm
	Pig	Income generation through sale of meat	On farm	Feeds are purchased for supplement	On farm
	Donkey	Income generation through transportation service	Marula farm, Delamere farm, KWSTI, Roadside		
	Bee	Income generation through sale of honey	Forest	None	N/A
Nakuru	Cattle	Family consumption of milk & Income generation through sale of meat and surplus milk	Mauche, Njoro, Elbagon, Molo, Mau Narok, Mau summit, Piave, Kapkures, Menengai Forest	None	?
	Goat	Income generation through sale of meat	Mauche, Njoro, Elbagon, Molo, Mau Narok, Mau summit, Piave, Kapkures, Menengai Forest	None	?
	Sheep	Income generation through sale of meat	Mauche, Njoro, Elbagon, Molo, Mau Narok, Mau summit, Piave, Kapkures, Menengai Forest	None	?

Table 3-5 Assessment of Livestock and Forage Resources Against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**High:** Livestock is very common and provides an important source of income to communities.
Interaction with drivers of change on ES or with Project operations	**High:** Some roadside grazing areas will be lost and access to grazing area and watering points could be reduced by road
Replaceability/Management potential	**Medium:** There are other natural or modified habitats that can offer foraging resources.
Priority Ecosystem Services	**PES Type 1**

3.1.1.3 FISHING AND FRESHWATER FISHERIES RESOURCES

Two types of fisheries occur along the proposed highway project: Inland freshwater fisheries and aquaculture. Table 3-6 provides an overview of fishing activities in each subcounty.

Aquaculture is limitedly practised and was mentioned only in Limuru, Mai Mahiu and Rongai sub-counties. It is practiced in individual artificial ponds for finfish species, Tilapia is the main species used in the ponds.

Inland freshwater fisheries are practised in rivers, dams and lakes. Sub-counties where freshwater fisheries are practised are Kinangop, Rongai, Naivasha, and Nakuru. Fishing activities in rivers is predominant in Njabini, Molo, Malewa and Njoro rivers. While in lakes, Lake Naivasha is a freshwater Lake which has a well-established fisheries management system, whereas Lake Nakuru is a saltwater lake where fishing is occasional. However, the government of Kenya recently banned the consumption of fish from Lake Nakuru because of chemical concentrations in fish[1]. Freshwater fisheries in lakes are mainly for commercial purpose while subsistence fisheries are more common in the rivers. Fish species caught in rivers are not well known by residents but in the lake, common species caught are Tilapia found in Lake Nakuru and Naivasha. Lake Naivasha has more diverse fishery species; including the Common Carps, Tilapia, Catfish and Large Mouthbash.

Fisheries in Lake Naivasha are managed by various Beach Management Units (BMU) at each landing site. The BMUs are composed of boat owners, fishermen, fish traders, ecotourism boat workers and input suppliers (motorbikes, shops). Fishing takes place throughout the year, but catches are more abundant from January to March. Fisheries in Lake Naivasha are affected by pollution caused mainly by the absence of wastewater management. Overfishing is also an issue and has caused a significant fishery collapse in the past. Fish is sold in various fish markets, but also on the highway roadside (Figure 3-1).

1 https://citizentv.co.ke/news/government-bans-consumption-of-fish-from-lake-nakuru-5043609/

Figure 3-1 Karagita Beach Landing and fish seller by the road in Naivasha

Table 3-6 Summary of fishing activities per sub-county

Sub-county	Type of Fisheries	Feature type	Location	Species	Use	Remark
Limuru	Aquaculture	Ponds	Not specified	Unknown	Subsistence use and sold	Very few people practise
Lari	None	N/A	N/A	N/A	N/A	N/A
Mai Mahiu	Aquaculture	Ponds	Not specified	Unknown	Subsistence	Very few people practise
Kinangop	Freshwater fisheries	Dam	Not specified	Crayfish	Sold	Very few people practise
		River	Njabini River	Trout	subsistence	Very few people practise
Kuresoi	None	N/A	N/A	N/A	N/A	N/A
Rongai	Freshwater fisheries	River	Molo River	Unknown	Subsistence	Very few people practise
	Aquaculture	Ponds	Not specified	Tilapia & Catfish	Subsistence and for sale	Very few people practise
Molo/ Koibatek	None	N/A	N/A	N/A	N/A	N/A
Gilgil	None	N/A	N/A	N/A	N/A	N/A
Naivasha	Freshwater fisheries	Lake	Kamere, Karagita, Kihoto, Tarambeta in Lake Naivasha. Malewa River	Common Carps, Tilapia, Large Mouthbash	Commercial	
Nakuru	Freshwater fisheries	Lake	Lake Nakuru National Park	Tilapia	Subsistence	Very few people practise
		River	Njoro River	Unknown	Subsistence & commercial	

Table 3-7 Assessment of Fishing and Freshwater Fisheries Resources against ES Prioritisation Criteria

Prioritisation criteria	Results
Level of Dependence on the ES	**Medium:** Commercial fishing is mostly important in the Lake Naivasha area. Subsistence fishing in rivers is practiced by a limited number of people.
Interaction with drivers of change on ES or with Project operations	**Medium:** Fish and fisheries can be temporarily affected by changes to water quality during project construction. However, water quality is already degraded, and the Project has no control over this pollution. Fish sellers by the side of the road will be displaced.
Replaceability/Management Potential	**Medium:** The rivers and Lakes where fishing is practiced is limited. Alternative fish selling locations can be found.
Priority Ecosystem Services	**Not a PES**

3.1.1.4 HUNTING AND BUSH MEAT

Hunting being illegal, it is not an important activity within the RAA. It is, however, practised secretly by a limited number of people. Sub-counties that mentioned hunting was practiced are Kinangop, Rongai, Molo/ Koibatek and Gilgil (Table 3-8). Commonly targeted species for bushmeat are antelopes, African hare and porcupines. Hunting takes place on farms near forests and inside forests in Rongai and Molo/ Koibatek subcounties. In Gilgil section, hunters intrude on Soysambu to hunt for antelopes, warthogs and African hare. Hunting in Rongai and Molo is mainly for subsistence but bushmeat is secretly sold in the Gilgil section.

Table 3-8 Summary of hunting per sub-county

Sub-county	Target Wildlife Species	Hunting Area	Reason for Hunting	Remark
Limuru	N/A	N/A	N/A	
Lari	N/A	N/A	N/A	
Mai Mahiu	N/A	N/A	N/A	
Kinangop	Antelopes, Hare, Porcupines	N/A	Subsistence	Illegal
Kuresoi	N/A	N/A	N/A	
Rongai	Antelopes, Hare	Farms near forest, inside Forest	Subsistence	Illegal
Molo/ Koibatek	Antelopes, Hare, Porcupine	Farms near forest, inside Forest	Subsistence only	Illegal
Gilgil	Antelopes, Hare, Warthog	Soysambu (Delamere farm)	Subsistence, trade	Illegal
Naivasha	N/A	N/A	N/A	
Nakuru	N/A	N/A	N/A	

Table 3-9 Assessment of Hunting and Bush Meat against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**Low:** Hunting is an illegal and very marginal activity. There are very few people who occasionally hunt.
Interaction with drivers of change on ES or with Project operations	**Low:** Interactions are deemed not to be significant as hunting activities are marginal in the area.
Replaceability/Management potential	**High:** Not requiring management.
Priority Ecosystem Services	**Not a PES**

3.1.1.5 WILD FOOD PRODUCTS

Many households in the project area supplement their diets with wild food products. The wildly gathered foods are mostly vegetables and fruits that have been traditionally used by the communities. Some wild vegetable species have been adopted into home gardens where they are produced in large quantities. During consultations with communities, six plant species used as a food product were identified. Table 3-10 lists all plants and their parts consumed by local communities. Maasai and Ogiek both confirm they collect wild fruit from the forests.

Table 3-10 List of plants consumed by local communities

Family	Scientific name	Local name	Part consumed	
			Leaves	Fruits
Solanaceae	*Solanum nigrum* (African Nightshade)	Managu (Kik. & Ogi.)	x	
Passifloraceae	*Passiflora mollissima* (Wild passion)	Manyatera (Kik.)		x
Solanaceae	*Physalis peruviana* (Cape berries)	Nathii (Kik.)		x
Amaranthaceae	*Amaranthus sp.*	Terere (Ogi.)	x	
Urticaceae	*Urtica dioica*	Kahurura (Kik.), Nderema (Ogi.)	x	
Cleomaceae	*Cleome gynandra* (Spider plant)	Saget	x	

The most common wild vegetable plant species is the *Solanum nigrum* (African Nightshade) which is locally known as Managu (Figure 3-2). This plant has been adopted in most homesteads and varieties that are less bitter in taste have been developed for commercial purpose. This vegetable was mentioned in most sections as a common meal sought from the forest. There are two ways wild Managu grows in the forest, naturally growing in openings in the forest, or adopted on the Shamba system practised in the forest (Kinale and Koibatek forests).

Figure 3-2 Managu leaves sold at the market in Molo

The species *Urtica dioica* (Stinging Nettle) was mentioned as a wild vegetable plant in the Kinangop and Kuresoi section. It is used for replenishment of calcium in the body and given to those with joint pain. Other wild vegetables are the *Amaranthus* (Terere-Ogiek) and Spider plant (Saget – Ogiek), which are widespread food resources in the western part of Kenya.

These vegetable plants are an important part of meals among Kenyans. Though originally found in the wild, the plants have been adopted into home gardens and currently create income to various households. In western Kenya, the vegetable plants are not collected from the wild; they grow on farms as perennial weeds which are retained due to their value. Seeds of the vegetable plants currently exist in different varieties and are grown in large gardens for commercial sales in large towns.

Wild fruit mentioned as being gathered in the study area include Wild Passion fruit (*Passiflora mollissima*) (Figure 3-3) and Cape Berry (*Physalis peruviana*) which are both introduced in the country. They are wildly spread by birds on the landscape and thus these plants can be found naturalized in forests and the bushland. The Cape Berry is an invasive species found in the forest and natural vegetation areas in croplands. Wild Passion fruit can be found growing along the hedge of farms and riverine areas.

Figure 3-3 **Wild Passion fruit (Passiflora mollissima): The vine of the plant (left) and the flower and the fruit (right)**

Besides wild vegetables and fruits, edible mushrooms are collected from Kinale forest, where they grow in areas with high humus (litter mulches). Hence, degradation of the forest is likely to affect their availability. Most of the mushrooms collected are sold in the nearby markets and along the highway.

The wild food plants have high nutrition benefits and are sought highly by residents for commercial purposes. These food resources are mostly found in the forest, hence are limited within human settled landscapes. As a result, very few people living near the forest have access to the wild vegetables and fruits with access permits. Women and children are mostly involved in the collection of vegetable plants, while all genders, especially youths are involved in the collection and selling of wild fruits. The products are sold along the highway on nearby trading/urban centres such as Kimende, Flyover and Total junction (Mau Summit) and are transported as far as Molo town, Nakuru, Naivasha and Nairobi.

Table 3-11 Assessment of Wild Food Products against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**Medium:** The consumption of wild food products is largely practiced by local communities along the road corridor.
Interaction with drivers of change on ES or with Project operations	**Medium:** Edible plants are mostly found in forests and will not be directly affected by the Highway Project. However, induced access might increase the harvesting pressure on these resources.
Replaceability/Management potential	**High:** Most of the wild food products consumed are widespread and are now grown on farms, hence they have high replaceability.
Priority Ecosystem Services	**Not a PES**

3.1.1.6 TRADITIONAL MEDICINE

A total of 51 plant species were recorded as medicinal plants along the sections of the proposed Nairobi – Nakuru – Mau Summit highway road (Table 3-12). The species most frequently mentioned for its medicinal use is *Prunus africana*. *Warburgia ugandensis, Azadirachta indica* and *Aloe* species were also very frequently recorded. However, the Ogiek vice chairman confirmed that they have up to 400 different species that they use for traditional medicine.

Maai Mahiu is the area where the most medicinal plants were mentioned and they constitute about 37% of medicinal plants, while Kuresoi and Molo/ Koibatek, each has 26% of the species. Sources of the medicinal plants are mostly in the protected forests (Kinale and Kijabe forests – in Kikuyu Escarpment Forest, Molo, Eburu, and Koibatek forests) managed by Kenya Forest Service (KFS) and riverine forests traversing farmlands. Entrance into the forest reserves to collect medicinal specimens requires a permit for access. However, in the Gilgil and Naivasha area, residents collect herbal specimens from the rangelands such as around Lake Elmentaita. The herbal specimens are mostly preserved by drying for longer shelf life and boiled in water to extract the benefits for treatments (Figure 3-4).

Figure 3-4 Dried herbs at local herborist shop

Table 3-12 List of plants used for traditional medicine

Family	Scientific name	Local name	Part used					Efficacy/Sickness
			Fruits	Leaves	Stems	Bark	Root	
Rosaceae	*Prunus africana*	Muiri (Kik.)				x		Allergy
		Tendwet (Ogi.)				x		Prostate cancer
Canellaceae	*Warburgia ugandensis*	Muthiga (Kik.)					x	Teeth ache
		Seget (Ogi.)						
Rhamnaceae	*Rhamnus prinoides*	Mukarakinga (Kik.)					x	Joint pain
Euphorbiaceae	*Croton dichogamus*	Kererwa (Kik.)					x	Arthritis (bone and joint pains)
Rutaceae	*Zanthoxylum usambarense*	Mugucwa (Kik.)				x		Swelling of salivary gland
Asphodelaceae	*Aloe sp.*	Mugwa-nugu (Kik.)		x				
Meliaceae	*Azadirachta indica*	Mwarumbaine (Kik.)		x				Malaria
Aquifoliaceae	*Ilex mitis*	Muthumara (Kik.)		x				Malaria, Typhoid ,Leg pains
Lauraceae	*Ocotea usambarensis*	Muthaithi (Kik.)					x	Broad spectrum of diseases
Malvaceae	*Dombeya sp.*	Mukeu (Kik.)					x	Joint pain
Loganiaceae	*Strychnos henningsii*	Muteta (Kik.)					x	Joint pains
Araliaceae	*Polyscias kikuyuensis*	Mutati (Kik.)					x	Knee joint pain, Barren women
Oleaceae	*Olea europaea*	Muthamayu (Kik.)					x	Joint pains, Cholesterol
Undetermined	*Undetermined*	Kiheha (Kik.)						Malaria, Pneumonia, Allergy
Apocynaceae	*Carissa edulis*	Mukawa (Kik.)					x	Barren women, General illness in children
Solanaceae	*Solanum sp.*	Mutongu (Kik.)					x	Stomach upset
Asteraceae	*Schkurhia pinnata*	Kahato (Kik.)		x				Malaria
Asteraceae	*Tagetes minuta*	Mubangi (Kik.)						
Undetermined	*Undetermined*	Omerangoyo *(Maa.)*			x			Malaria, Pneumonia & High Blood Pressure (used with a concoction of Nkamai)

Family	Scientific name	Local name	Part used					Efficacy/Sickness
			Fruits	Leaves	Stems	Bark	Root	
Rhamnaceae	*Rhamnus staddo*	Olkokola (Maa.)					x	Malaria, Pneumonia & High Blood Pressure
Undetermined	*Undetermined*	Nkamai (Maa.)				x		Added to Olkokola, and Omerangoyo concoctions to improve efficacy
Undetermined	*Undetermined*	Olokerdangai (Maa.)		x				Given to women who deliver after two days preventing protrusion of stomach
Combretaceae	*Combretum mole*	Olmororoi (Maa.)		x				Added to Olokerdangai to improve efficacy
Urticaceae	*Urtica dioica*	Kahuhura (Kik.)		x				
Apocynaceae	*Carissa spinarum*	Olmariaki (Maa.)					x	Sexually Transmitted diseases (gonorrhea, Syphilis)
Ericaceae	*Agauria salicifolia*	Olagumatik (Maa.)					x	Added to Olmariaki to improve efficacy
Solanaceae	*Solanum dennekense*	Oltulele (Maa.)		x				Sexually Transmitted Diseases (Gonorrhoea, Syphilis etc.)
Celastraceae	*Mystroxylon aethiopicum*	Olodon'ganayoi (Maa.)					x	Added to Oltulele to improve efficacy
Undetermined	*Undetermined*	Olkesikon'gu (Maa.)				x	x	Stomach ulcer and Arthritis
Undetermined	*Undetermined*	Oloyapasei (Maa.)					x	Kidney and Liver diseases, and blood cleansing
Undetermined	*Undetermined*	Nkekambaus (Maa.)		x				Added to Oloyapasei to improve efficacy
Salicaceae	*Trimeria grandifolia*	Oledat (Maa.)					x	Added to Oloyapasei to improve efficacy
Lamiaceae	*Plectranthus barbatus*	Maronget (Ogi.)		x				Cancer and stomach upset (used in concoction of Sinendet)
Apocynaceae	*Carissa edulis*	Chebindorwet (Ogi.)		x				Chickenpox
							x	Cold/Flu (used in concoction of Lakiat and Sinendet)
Rhamnaceae	*Undetermined*	Lakiat (Ogi.)		x				Added to Chebindorwet, Sergutiet to improve efficacy

Family	Scientific name	Local name	Part used					Efficacy/Sickness
			Fruits	Leaves	Stems	Bark	Root	
Apocynaceae	*Pericloca linearifolia*	Sinendet (Ogi.)		x				Added to all herbal concoctions of Ogiek community to reduce bitterness
Euphorbiaceae	*Clutia abyssinica*	Gurumanyat (Ogi.)		x				Chest pain
Rhamnaceae	*Rhamnus prinoides*	Kosisitiet (Ogi.)					x	Broad spectrum of diseases (used in conconction of Lakiat and Sinendet)
Poaceae	*Eleusine jaegeri*	Sergutiet (Ogi.)					x	Applied in concoctions of Gurumanyat, Kosistiet and Sinendet on general sickness in women and children
Asteraceae	*Tarchonanthus camphoratus*	Lelechwet (Ogi.)		x				Stomach upset
Undetermined	*Undetermined*	Mueno (Kik.)						ND
Undetermined	*Undetermined*	Wanjiru-Waweru (Kik.)		x				ND
Asteraceae	*Tagetes erecta*	Mexican Marigold (Com.)		x				Bleeding on cuts
Euphorbiaceae	*Ricinus communis*	Castor Oil Plant (Com.)	x					Family planning
Undetermined	*Undetermined*	Kitoloswa (Maa.)					x	Malaria
Rutaceae	*Vepris simplicifolia*	Orgelai (Maa.)					x	Used with Kitoloswa to improve efficacy
Undetermined	*Undetermined*	Loiborbene (Maa.)		x				Pneumonia
Undetermined	*Undetermined*	Oroteti (Maa.)		x				Used with Loiborbene to improve efficacy
Verbenaceae	*Lippia javanica*	Osinoni (Maa.)		x				Indigestion
Capparaceae	*Maerua angolensis*	Olomaloki (Maa.)					x	Typhoid
Apocynaceae	*Carissa edulis*	Olomoriaki (Maa.)		x				Used with Olomaloki to improve efficacy

They are used for various symptoms and diseases, with many species being used for joint pain (Arthritis), allergies and malaria (Table 3-12). Treatment of allergies is mostly done among the Kikuyu, Ogiek and Maasai communities using *Prunus africana*. Maasai, Ogiek and Kikuyu communities show differences in the medicinal plants they used, but five species are used commonly by the Kikuyu and Ogiek communities. These include *Carissa edulis*, *Prunus africana*, *Rhamnus prinoides*, *Urtica dioica*, *Warburgia ugandensis*. This similarity can be attributed to resemblance in climatic condition of localities where Ogiek and Kikuyu communities live.

Some medicinal plants are used in combination with other plants in order to improve on efficacy in concoctions. These form about 22% of the medicinal plants along the proposed highway. The practice of combining more than two species for making medicinal concoction is common with the Maasai and Ogiek community. Efficacy of most plants are derived from their roots; with leaves and bark also used for some plants. Plants of which the bark is collected include *Prunus africana*, *Zanthoxylum usambarense*, Nkamai (Maa.), Olkesikon'gu (Maa.). Plants from which bark tissue is harvesting can be heavily affected as opposed to those with tissues extracted from leaves and roots. Due to the appreciated medicinal benefits of the *Prunus africana* bark, the plant has become vulnerable under the IUCN red list of species. Aloe species are also generally threatened by trade for their specimens. As such, it is enlisted in the CITES appendix II where trade overall or specimens is banned.

Residents of the project area have limited knowledge on the efficacy of these plants. However, the use of *Prunus africana* is very popular for the treatment of allergies and cancer. The species mostly occurs in forest, but some scanty distribution is also found on a few individual farms where they are preserved for medicinal use.

There are few traditional medicine practitioners in the communities along the proposed highway. Most of the practitioners provide services by referral from people cured previously. Others sell herbal specimens in open markets and very few have an established clinic for administration of the service. Most communities mentioned the use of traditional versus modern medicine as about 50/50. Traditional medicine is often more easily accessible and consumed as the first alternative whenever they are unable to buy conventional medicines. Herbal medicines are generally used for first aid, and as complementary medicines especially in the treatment of cancer.

Distribution of some medicinal plants is largely affected by the landscape. These are limited due to land degradation that has seen indigenous tree species disappearing from the cropland. Two medicinal plants are mentioned by Maasai medicinal practitioners to have disappeared in rangeland around Mai Mahiu, even though they are available in the protected forest area. These include *Rhamnus staddo* (Olkokola, Maa.) and *Osyris lanceolata* (Olosesiai, Maa.). However, access of the medicinal resources in the protected areas are also restricted and strictly controlled by issuance of permits. Some of the medicinal plants are enlisted under the IUCN red list of threatened species while others are on CITES which banned trade as a whole or part of the plant species. These restrictions by forest managers and the disappearance of the plant species in cropland has reduced the reliance on them as medicinal plants for treatments.

Table 3-13 Assessment of Traditional Medicine against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**High:** Traditional medicine is still used a lot among the residents of the study area, although knowledge on them is sparse. Traditional practitioners make use of locally harvested medicinal plants.
Interaction with drivers of change on ES or with Project operations	**Medium:** Medicinal plants are mostly found in forests and will not be directly affected by the Highway Project. However, induced access might increase the harvesting pressure on these resources.
Replaceability/Management Potential	**Medium:** A lot of plants used can be bought at markets. Also, the fact that more than one plant can cure the same illness reduces the dependence on some species and increases their replaceability.
Priority Ecosystem Services	**PES of Type I**

3.1.1.7 BUILDING, CARPENTRY AND CRAFT MATERIALS

Building materials occurring along the proposed highway road are timber, poles and mineral construction materials. The distribution of timber is dominant in Limuru, Lari, Mai Mahiu, Kinangop, Rongai, Molo/ Koibatek and Gilgil. Some of the timber mentioned in these areas comes from farms while others are purchased from timber yards (sawmills). Most of the timber yards get their timber from local farms from where they are produced in various sizes for building. Timber yards are situated in urban or town centres in some of the highway sections. Tree species common in the area for timber production are *Cupressus lusitanica, Pinus pitula, Eucalyptus saligna*, while *Grevillea robusta* is in the Kinangop area. In the Maai Mahiu, Naivasha and Nakuru timber for construction was only purchase. Only Kuresoi community representatives mentioned some residents illegally acquired poles for construction from the Kuresoi forest.

Maasai communities construct their houses (manyattas) out of local wood, mud and manure. Trees species collected within the village are– camphor bush – *Tarchonanthus camphoratus* (Leleshwa in Maasai), Brown Olive tree –*Olea Africana* (Oloirien in Maasai), East African greenheart tree - *Warburgia ugandensis* (Osogonoi-Maasai) and Honey Acacia - Acacia mellifera (Oiti).

Houses amongst the Ogiek are made from Bamboo, Olive tree and Red cedar. Recently they introduced thatched walls with iron sheet roofing because of inaccessibility of the preferred tree species.

Mineral construction materials are also exploited, including stones and sand for building, and gravel for road construction. These resources are obtained from the Kikuyu escarpment in the Kinangop area.

Carpentry is practiced by a few households along the highway, mostly using timber resources from sawmills, notably cedar, for making chairs and beds that are sold in urban centers and towns. Some craftsmen were observed selling their products by the side of the road in the Koibatek Forest (Figure 3-5). These prune cedar branches in farms and forests (Koibatek, Molo Forests) are used to build chairs.

Craft work is very limited in the area. For instance, bamboo is used only in Lari for making baskets, utilized for carrying tea leaves from farms. Bead work among Maasai community in the Gilgil section uses synthetic raw materials which are purchased. No local resources are used for making beads and other craft work by the Maasai in the area.

Figure 3-5 Carpenters building and selling chairs along the Highway

Table 3-14 Assessment of Building, Carpentry and Craft Material against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**Medium:** Most building and carpentry materials are purchased in timber yards. The practice of carpentry and crafts is limited within the project area. However, the Project is dependent on the availability of construction material such as sand and gravel, that will be provided in the study area.
Interaction with drivers of change on ES or with Project operations	**Low:** The interaction is low as the project will not affect the availability of building, carpentry and craft material.
Replaceability/Management potential	**High:** Since most of the timber is purchased and can come from areas outside the study area, the replaceability of building, carpentry and craft materials is deemed high.
Priority Ecosystem Services	**Not a PES**

3.1.1.8 BIOFUEL

Biofuel resources along the proposed highway road are mainly firewood. Charcoal is used only in urban areas, where it is purchase in markets, and by the Ogiek community in Eburru, where it is made solely for household use from their own tree plantations. The use of biogas and sawdust as heating is limited to Kinangop sub-county. In most areas, residents access forest for firewood. Forests accessed for firewood include Kinale, Kijabe, Kuresoi and Molo forests. Charcoal is obtained by residents by purchasing them from local vendors. Most of charcoal sold by vendors is imported from outside the study area. Narok is highlighted as the main source of importation of firewood and charcoal to the project area. Residents do not have the choice of tree species for firewood and charcoal; they buy whatever is available in the market. For the residents to access the forest, they require a permit from the Kenya Forest Service which runs for a year. Collection of firewood in the forest is done mostly by women, men doing it especially for trade in local markets.

Table 3-15 Assessment of Biofuel against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**High:** Local communities rely on biofuel as the main source of energy.
Interaction with drivers of change on ES or with Project operations	**Medium:** Forests where firewood is collected will not be directly affected by the Highway Project. However, induced access might increase the harvesting pressure on these resources and the road can create a barrier to access nearby firewood for daily collection of firewood.
Replaceability/Management Potential	**Medium:** As the main source of energy, the replaceability of the biofuel is limited. However, firewood can be purchased, as already done by some residents.
Priority Ecosystem Services	**Not a PES**

3.1.1.9 WATER RESOURCES

The proposed Nairobi – Nakuru - Mau Summit Highway traverses a landscape with diverse topographical features and climatic conditions which influence water resources in the area. Water resources mentioned by the community representatives were rivers/streams, springs, swamps, water pans, dams, lakes, rainwater collection facilities, boreholes and water supply infrastructures (pipes). Water sources change from one sub-county to another (Table 3-16).

These constitute sources of water for domestic use, as well as for agriculture and livestock. In some areas where water resources are scarcer, water is bought from vendors. Water thus also represents a source of income for some water vendors which will transport and sell water.Water vendors are common in Molo/ Koibatek, Naivasha and Maai Mahiu sub-counties where many households rely on water vendors during the dry seasons.

Table 3-16 Summary of water resources per sub-county

Sub-County	Water Resources	Names	Level of Use/Distribution	Remark
Limuru	Rainwater	Households	Very High	Only few residents with storage facility uses rain water for better part of the year
	Pipe water	Bibiriani, Ngenia, and Limuru Water Project	High	Limuru Water Project also serves Mai Mahiu area.
	Borehole	Ngenia, Roremo	Low	It serves water pipelines throughout the year
	Springs	Roremo	Low	Few people access the spring area
Lari	Rainwater	Households	High	Only few residents with storage facility uses rain water in better part of the year
	Pipe water	Bathi Water Project, Limuru Water Project	Moderate	
	River	Bathi River	Moderate	Mostly used by livestock
	Dam	Bathi Dam	Low	
Mai Mahiu	Rainwater	Households	High	Only few residents with storage facility uses rain water in better part of the year
	Pipe water	Limuru Water Project	Low	It serves few populations. Water supplied mostly by vendors
	Borehole	-	Low	Salty water. Less attractive for use. Water supplied mostly by vendors
	River	Tongtong Stream	Low	Seasonal flow. Water supplied mostly by vendors
	Vendors	Distributed all over	High	Source water from stream, borehole, and specific points with tap water
Kinangop	Rainwater	Households	High	Only few residents with storage facility uses rain water in better part of the year
	Borehole	-	Moderate	
	River	River Njambini	Low	It is far from the road section
	Dam	Thiririka dam, Matches dam & Motonyora C dam (under rehabilitation)	Low	Livestock drinking water and washing farm products like carrots
	Shallow Well	-	Moderate	Quality affected during rainy season
Kuresoi	Rainwater	Households	High	Only few residents with storage facilities use rainwater in better part of the year
	River	Kiptagich, Total Rivers	High	Upper part of Kiptagich is cleaner than lower part after it crosses the road
	Springs	Karunga, Ararwet, Ngozi springs	Low	Discharge is high during rainy season. Karunga spring is near the road reserve
	Pipe water	NARUWASCO, KPC & Catholic Diocese	Low	
Rongai	Rainwater	Households & Ngata	High	Only few residents with storage facility uses rain water in better part of the year
	River	Rongai & Molo River	Moderate	Used for irrigation along the river
	Dam	Mambo Mambo dam	Low	Privately owned
	Boreholes	Wakarimu & Sobea	Moderate	Freshwater

Sub-County	**Water Resources**	**Names**	**Level of Use/Distribution**	**Remark**
	Pipe Water	NARUWASCO	Moderate	Accessed by residents along the highway pipeline is aligned
	Springs	Bomasan, ACK & Jogoo	Low	
Molo/ Koibatek	Pipe Water	NARUWASCO	Low	
	Vendors		High	
	Springs	Nguzo, Jogoo spring	Low	Occur in Koibatek Forest
	River	Molo River	Moderate	
	Rainwater	Households	High	Only few residents with storage facility uses rain water in better part of the year
Gilgil	Pipe water	NARUWASCO	High	
	Rainwater	Households	High	Only few residents with storage facility uses rain water in better part of the year
	Springs	Diatomite	Low	Hot spring
	Stream	Kariandusi	Low	Used mostly by livestock during dry season
	Dam	Kikopey	Low	Used mostly by livestock
Nakuru	Pipe water	NAWASCO & KONOIKE	High	
	River	River Njoro & Pwani	Low	Draining into Lake Nakuru
Naivasha	Borehole	Dairy Training Institute (DTI), Around Delamere, others are Privately owned	High	Water is salty
	Pipe water	Naivasha Water Supply	Low	Piped borehole water
	River	Karati	Low	Seasonal river
	Lake	Lake Naivasha	Low	Used for domestic activities except drinking
	Vendors	Distributed all over	high	20 liters of water is sold at KES 10/=
	Water Shops	Distributed all over	Low	Water distilled from borehole
	Rainwater	Households	High	Only few residents with storage facility uses rain water in better part of the year

According to the community representatives in the focus groups, the most common source of water along the highway is rainwater which is harvested from roof catchments. Though this source is only reliable during the rainy season and requires large storage facilities, it is the most common source of water throughout the study area. Its sustainability depends on the size of the water storage facility owned by an individual household. Very few households have a significant water storage facility to sustain longer than a year.

Most sub-counties in the project area have some water supply infrastructure (pipe water), which transports water to towns from adjacent springs, boreholes or dam systems. However, most households are not directly connected to the pipe water. Only in Nakuru, Gilgil and Limuru do some households have tap water in their homes.

Rivers and streams are sources of water in most sub-counties, except in the Limuru area. The residents of Kuresoi and the Maasai Community South of Maai Mahiu highly depend on the river water more than other parts of the highway. Highway sections such as Lari, Rongai and Molo/ Koibatek are moderately served by river water for domestic use. Water from streams and rivers is also used for agriculture irrigation and for washing of vegetables such as carrots (Figure 3-6).

Figure 3-6 Carrot washing using stream water in Kijabe

Borehole water is unevenly distributed within the study area. Borehole water served many residents in Naivasha more than other parts of the sections along the highway. Sections of Kinangop and Rongai moderately use borehole water. Low coverage of borehole water is found among residents in the Limuru and Maia Mahiu subcounties. Other sections of the highway do not have borehole water adjacent to the proposed highway project.

Springs are present in Limuru, Kuresoi, Rongai, Molo/ Koibatek and Gilgil. Dams (reservoirs) are present in Lari, Kinangop, Rongai and Gilgil sections of the highway. The Ogiek community in Eburru sources their drinking and cooking water from geyser steam. Only a few locations in the area have enough steam to be tapped

Table 3-17 Assessment of Water Resources against ES Prioritisation Criteria

Prioritisation criteria	Results
Level of Dependence on the ES	**High:** Dependence of water is high, and it influences human health and communities' economy based on natural resources.
Interaction with drivers of change on ES or with Project operations	**High:** The project might have temporary impacts on streams/river water resources during the construction. The highway can be a barrier to access the nearest water source.
Replaceability/Management potential	**Low:** Replaceability is deemed low.
Priority Ecosystem Services	**PES of Type I**

3.1.2 REGULATION SERVICES

Regulation services were not systematically discussed with community representatives during focus groups/mapping sessions. However, literature and other baseline surveys (air, water quality, etc.) were used to describe their importance within the Project area.

3.1.2.1 AIR QUALITY CONTROL

Air pollution has negative consequences for human health and is associated with respiratory and cardiovascular diseases, as well as some forms of cancer. Baseline studies demonstrated standards for particulate matter that already exceeded criteria, especially in dense urban settings.

Roads, especially the traffic they generate reduce air quality. Vegetation cover plays an important role for erosion control and consequently air quality protection. The presence of water, moist habitat types and ambient moisture during the rainy season play an important role in natural dust abatement. Restoration of vegetation can reduce air pollution and serve as a cost-effective means for offsetting road impacts on air quality and ensuring regulatory compliance of the road project.

Table 3-18 Assessment of Air Quality Control against ES Prioritisation Criteria

Prioritisation Criteria	**Results**
Level of Dependence on the ES	**Medium:** Densely populated areas along the Highway would benefit from better air quality. However, air quality control by ecosystems is considered limited, as air quality is already degraded in the project area.
Interaction with drivers of change on ES or with Project operations	**High:** Temporary negative impacts on air quality are expected during construction. However, air quality throughout the operation of the project is not expected to be affected negatively due to emissions associated with congestion or poor road maintenance. Furthermore, the project will not significantly affect vegetation which can contribute to better air quality.
Replaceability/Management potential	**High:** Vegetation along the highway can be restored to improve air quality
Priority Ecosystem Services	**Not a PES**

3.1.2.2 CLIMATE REGULATION

The consequences of increased carbon dioxide and other greenhouse gases in the atmosphere are felt by people around the world through the impacts of climate change on rainfall patterns, storm frequency and severity, temperature, and sea-level rise. By storing carbon in vegetation, ecosystems keep carbon dioxide out of the atmosphere, where it would otherwise contribute to climate change. Restoration of vegetation can offset carbon emissions associated with road construction, leading to a carbon-neutral project. It can also help offset CO_2 from increased road traffic and conversion of vegetation which can be caused directly or indirectly from road construction.

Table 3-19 Assessment of Climate Regulation against ES Prioritisation Criteria

Prioritisation Criteria	**Results**
Level of Dependence on the ES	**Low:** The contribution to global climate regulation is considered low due to the vegetation state in the RAA, which is fairly degraded.
Interaction with drivers of change on ES or with Project operations	**Medium:** Interaction is medium as the project will not lead to an important loss of habitats and modelling results show a reduction of GHG emissions with the Project
Replaceability/Management potential	**High:** Vegetation along the highway can be restored to offset some ghg emissions
Priority Ecosystem Services	**Not a PES**

3.1.2.3 WATER REGULATION AND EROSION CONTROL

Vegetation holds soil in place and captures sediment, preventing erosion and keeping sediment out of drainage systems and waterways. Soil erosion is widespread and affects adversely all natural and human-managed ecosystems. Severe erosion can easily be triggered from lack of vegetation protection (Canton et al., 2001; Ludwig et al., 2005). It can cause soil deterioration (Marques et al., 2008), decline in land productivity (Pimentel and Kounang, 1998; Lantican et al., 2003) and degradation of streams, lakes and estuaries with transported sediments and pollutants. Vegetation, especially forested habitats, plays a significant role in soil erosion control. Their role is increased in areas with strong slopes. Riverine forests also play an important role for the control of erosion from water action.

Riverine vegetation and swamps can also play an important role in controlling the extent of flooding during rainy season. Furthermore, they can reduce the impact of evaporation during dry season by their shading effect. The vegetation throughout the extended study area, and the type of land use, are parameters that govern the infiltration of precipitation feeding surface and ground water resources. Forested areas, including sand forests, swamp forests, riverine forests and littoral forests, reduce the velocity of draining water facilitating its infiltration. As most people in the study area use groundwater, the water they drink is purified by the above ground natural habitat and through infiltration inside geologic layers as well.

Flooding and droughts were mentioned as being an important recurring problem for agriculture in some areas, which shows the importance of water regulation services amongst the communities.

Table 3-20 Assessment of Water Regulation and Erosion Control against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**High:** Dependence on water is high for local communities to cover their daily needs. Water management is also an important issue for the project.
Interaction with drivers of change on ES or with Project operations	**High:** Water regulation and soil erosion can have a great impact on the project. Reduced sediment in runoff and regulation of runoff can reduce sediment scour to roads and bridges, lowering infrastructure and vehicle maintenance costs.
Replaceability/Management potential	**Low:** Replaceability is deemed low as it is related to local natural processes.
Priority Ecosystem Services	**PES of Type I and Type II**

3.1.3 CULTURAL SERVICES

3.1.3.1 SACRED COMPONENTS

Cultures of local communities living along the proposed highway project have unique ways of interacting with their environment. They regard some places and environmental entities as sacred in their day lives. This is more pronounced among the Kikuyu community where some trees such as the *Ficus thoningii* (Mugumo tree), *Ficus sycomorus* (Mukuyu), and *Albizia gummifera* (Mukuruweini) are sacred due to their beliefs. Mugumo tree was also mentioned as a sacred tree for the Ogiek community in Eburru. No sacred sites were cited by the residents to be present at the project area. Although the Kikuyu community know of sacred trees, they hardly perform rituals or pray under these trees anymore. However, it has been mentioned that this type of cultural practice is still strong in areas such as Muranga and Nyeri. Moreover, in Nakuru, residents account for the presence of caves in Menengai crater where offerings are done by religious leaders. A group of Rastafarians associated also go to Menengai Crater to pray.

The Ogiek community in Mariashoni use caves inside the Mau Forest for prayers especially for the non-Christians. As for rites of passage (circumcision) ceremonies, they are held them under podo trees (*Podocarpus latifolius*). The trees therefore have cultural significance to the community.

Finally, Nakuru residents mentioned Jacaranda trees had significant cultural importance in the city. The trees have become part of the townscape and the residents have become very protective of these trees. In 2007, there was a quarrel between the Nakuru Municipal Council and the China Road and Bride Company when they cut down 2000 Jacaranda trees during the expansion of the road entering Nakuru (Gicinga, 2021). Table 3-21 presents a summary of sacred components mentioned by community representatives in each sub-county.

Table 3-21 Summary of sacred components per sub-county

Sub-County	Sacred tree Species	Sacred Site	Remark
Limuru	*Ficus thoningii* (Mugumo tree)	None	Residents believe the tree is sacred, but they do not perform rituals as they did traditionally
Lari	*Ficus thoningii* (Mugumo tree)	None	Residents believe the tree is sacred, but they do not perform rituals as they did traditionally
Mai Mahiu	*Albizia gummifera* (Mukuruwe)	None	Residents believe the tree is sacred, but they do not perform rituals as they did traditionally
	Ficus sycomorus (Mukuyu)		
	Ficus thoningii (Mugumo)		
	Adenim obesum (Oleteti tree)		Mentioned by the Maasai community members
Kinangop	None	None	N/A
Kuresoi	*Ficus thoningii* (Mugumo tree)	None	Residents believe the tree is sacred, but they do not perform rituals as they did traditionally
Rongai	None	None	N/A
Molo/ Koibatek	None	None	N/A
Gilgil	None	None	N/A
Naivasha	None	None	N/A
Nakuru	Jacaranda tree (cultural value)	Menengai caves, Menengai crater, Menengai Forest	Menengai caves are used by church leaders to offer prayers. Menengai crater is used by the Rastafarians. Menengai forest is used by the religious leaders

Table 3-22 Assessment of Sacred Components against ES Prioritisation Criteria

Prioritisation Criteria	Results
Level of Dependence on the ES	**High:** Even with ongoing modifications to local beliefs, the species that have cultural or sacred value are important to the local communities
Interaction with drivers of change on ES or with Project operations	**Low:** Tree cutting will be limited and there is a low risk that sacred trees will be affected by the project.
Replaceability/Management potential	**Medium:** Rituals to be undertaken and possibilities to move or replace the identified trees need to be discussed with local communities.
Priority Ecosystem Services	**Not a PES**

3.1.3.2 TOURISM AND RECREATION

The natural sites within the project area attract a significant number of tourists to the area. Nakuru County attracts a large inflow of tourists from within and outside Kenya with its diverse flora and fauna. The county's three national parks, Lake Nakuru National Park, Hells Gate National Park and Mount Longonot National Park, are major tourist attractions. Other tourist sites mentioned by the community representatives include Menengai Crater, Lake Naivasha, Lake Elmentaita, and Hyrax Hill prehistoric site. Private wildlife conservancies that attract tourists include Marula, Oserian and Kedong in Naivasha sub-county and Kigio and Soysambu in Gilgil sub-county. The main tourist activities include bird-watching, hiking, picnics, excursions and game drives (County Government of Nakuru, 2018).

Forests in Kiambu County (Kikuyu Escarpement, Kijabe Forest, Kereita Forest) attract a large number of domestic tourists annually. The main activities in these sites are site seeing, viewing of the Great Rift Valley, zip lining, hiking trails, etc. The County's attractions sites, hospitality sector (hotels and bars) and golf clubs also benefits from their proximity to Nairobi (County Government of Kiambu, 2018).

In general, tourism provides work for residents in different hotels and restaurants, who also purchase local food produce. Maasai communities receive local tourists from Nairobi and guide hiking activities in the Kikuyu Escarpment Forest. Ogiek in Eburru and Mariashoni also conduct eco-tourism, including bee keeping and herbal medicine trips and host guests in their community

Table 3-23 Assessment of Tourism and Recreation against ES Prioritisation Criteria

Prioritisation Criteria	**Results**
Level of Dependence on the ES	**High:** Tourism in the RAA is an important economic activity which relies on the beauty and conservation of habitats within protected areas of the RAA.
Interaction with drivers of change on ES or with Project operations	**Low:** The project will not have direct impacts on the protected areas on which tourism relies in the RAA. The road will have a positive impact by improving the access to the area.
Replaceability/Management potential	**Low:** Tourist attractions in the RAA and the unique habitats they constitute are highly specific ES, with no alternatives easily accessible or effective.
Priority Ecosystem Services	**Not a PES**

3.1.4 SELECTION OF PES

Based on the ES analysis, the identified PES are as follows:

- Agricultural potential and production;
- Livestock and forage resources
- Traditional medicine;
- Water resources;
- Water regulation and erosion control;

They are mainly PES of Type I associated with the provisioning services, confirming that well-being of local communities is profoundly related to natural resource exploitation. Water regulation and erosion control is a major concern for project operations and is thus considered as a PES of Type II as well.

The ES considered as priority by the local communities are agriculture, livestock and water resources. These ES are all part of the PES identified as part of the ES analysis.

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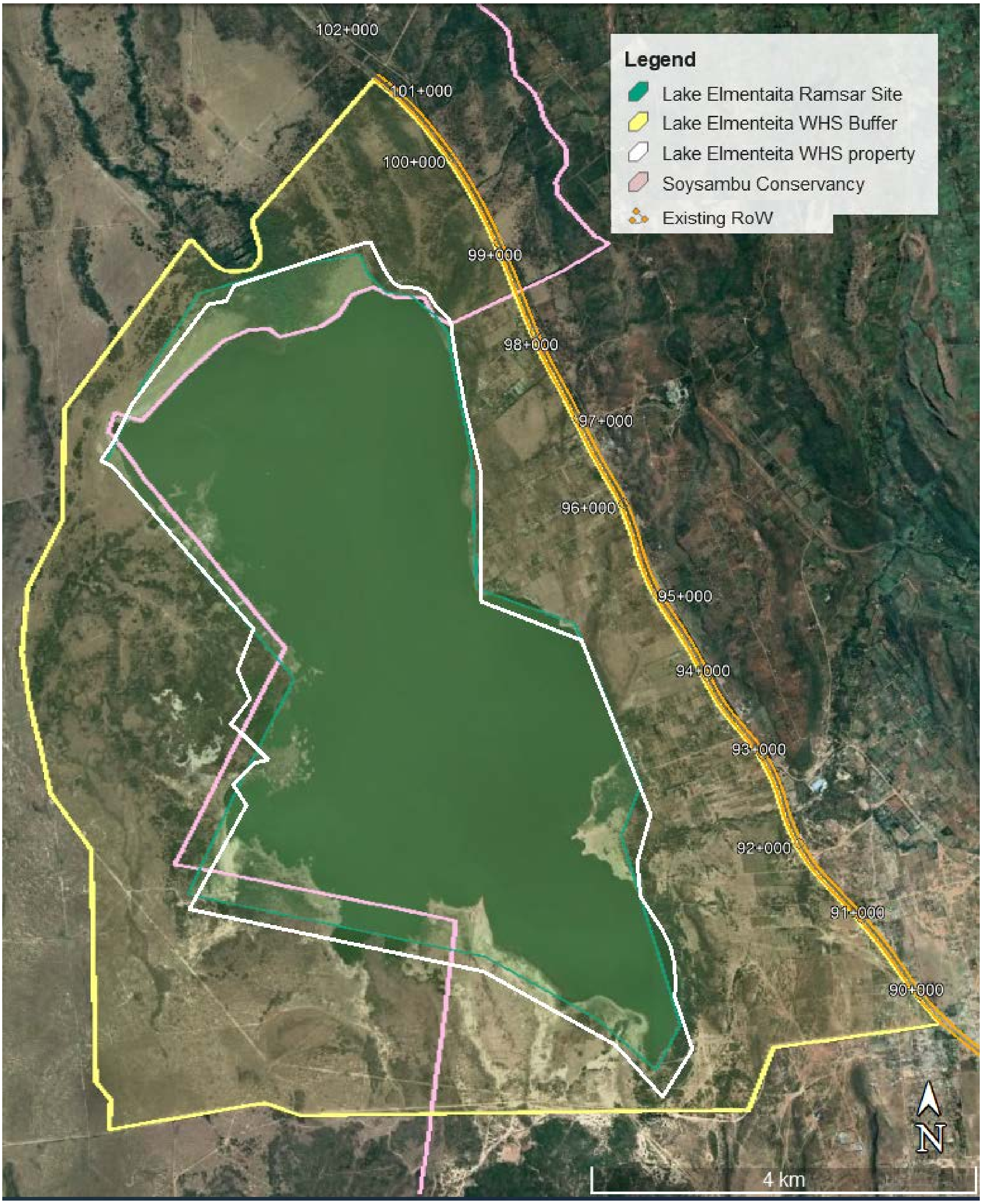
APPENDIX

6-25 *MAPS OF PROTECTED AREAS AND CONSERVANCIES*

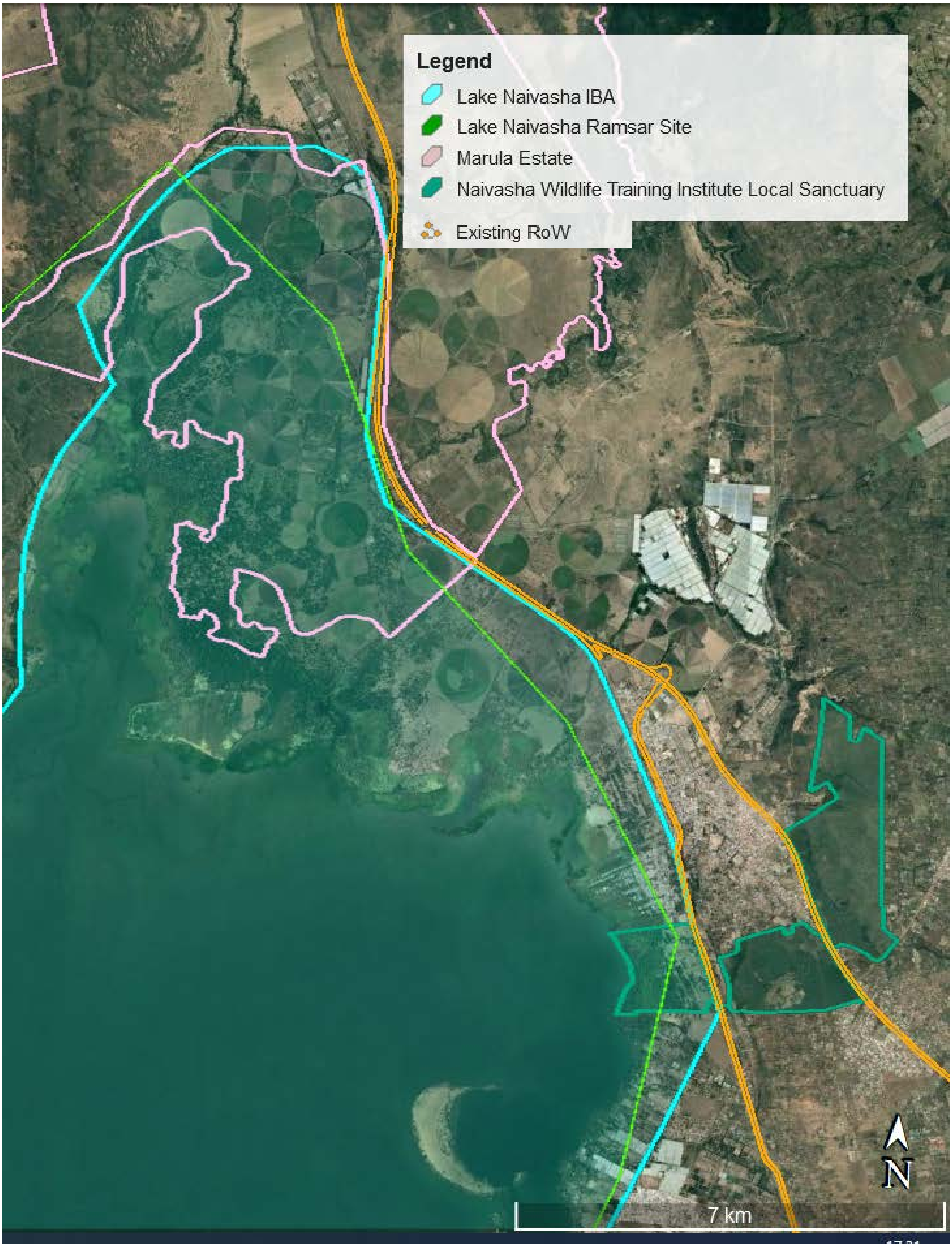
ZOOMED IN MAPS OF PROTECTED AREAS AND CONSERVANCIES IN CLOSE PROXIMITY TO THE HIGHWAY

Lake Nakuru National Park (About 350 m from RoW)



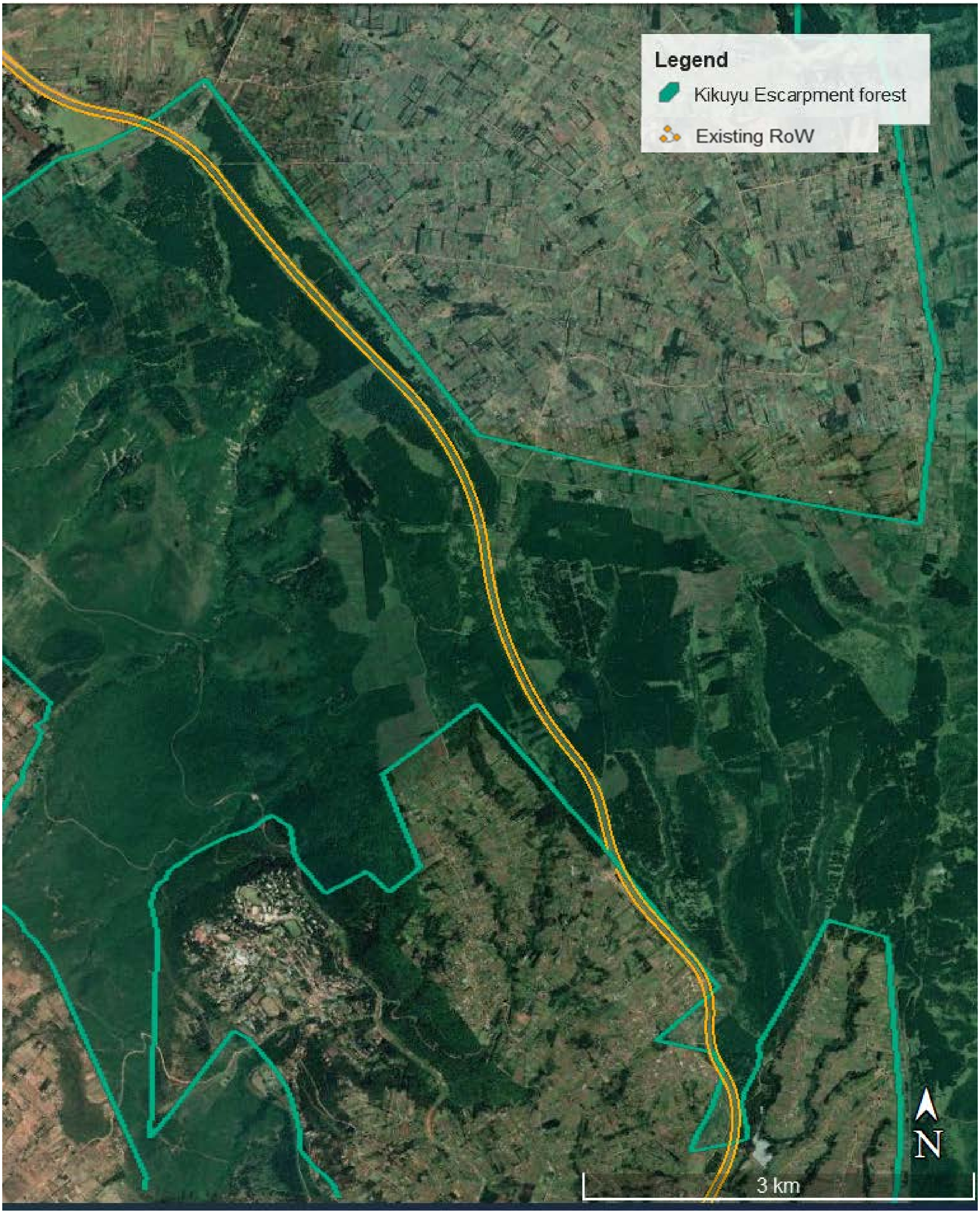
Lake Elmentaita World Heritage Site and Ramsar Site (Site about 860 m from the RoW. Buffer zone adjacent to the RoW along about 11.5 km)

Mount Londiani Forest Reserve/Public Forest (RoW crosses the site along 5.6 km)



Lake Naivasha Ramsar Site and IBA (Ramsar site about 90 m from RoW; RoW along IBA for about 11.2 km)

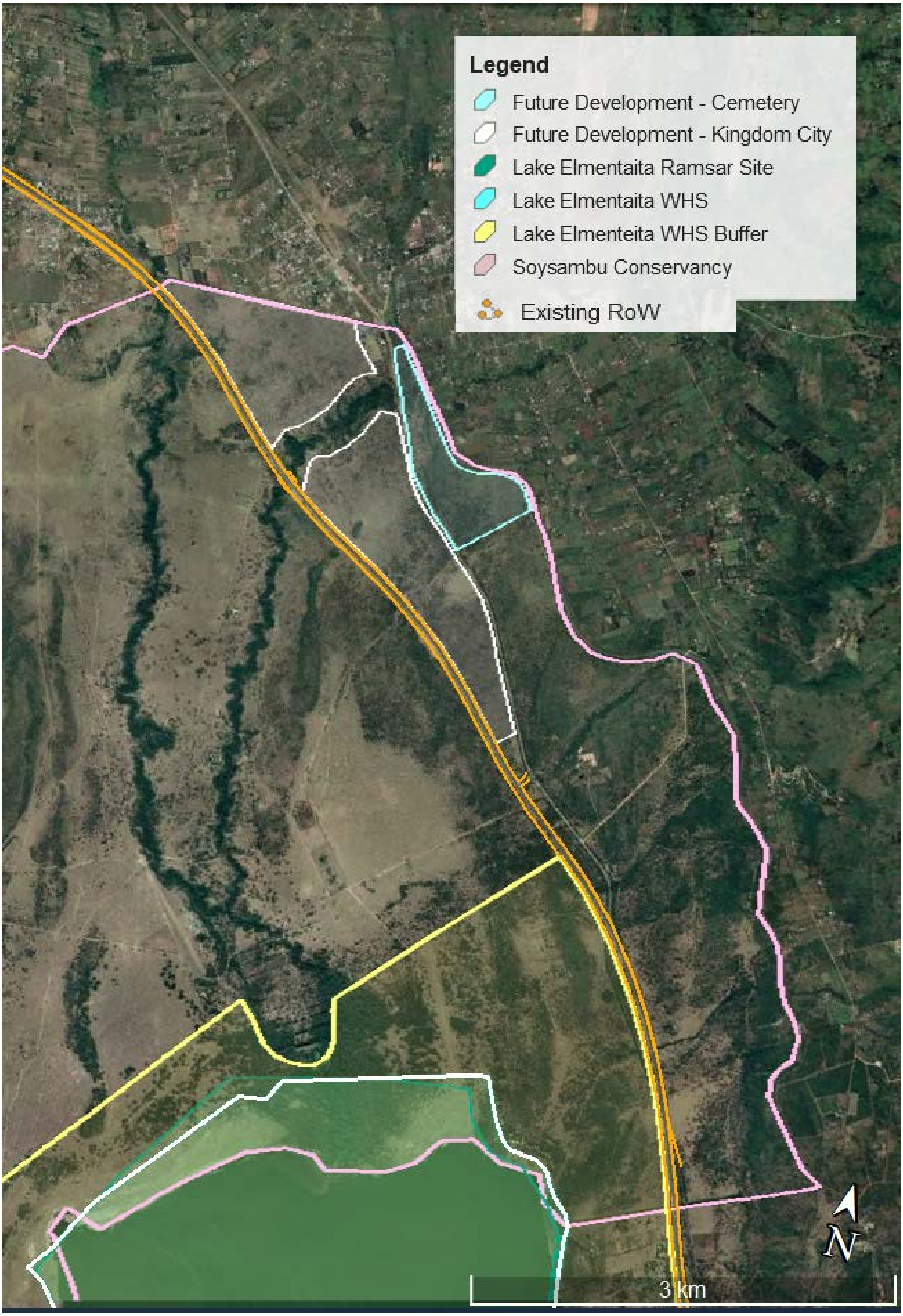
Kinangop Grassland IBA (RoW crosses the site along 4.5 km)



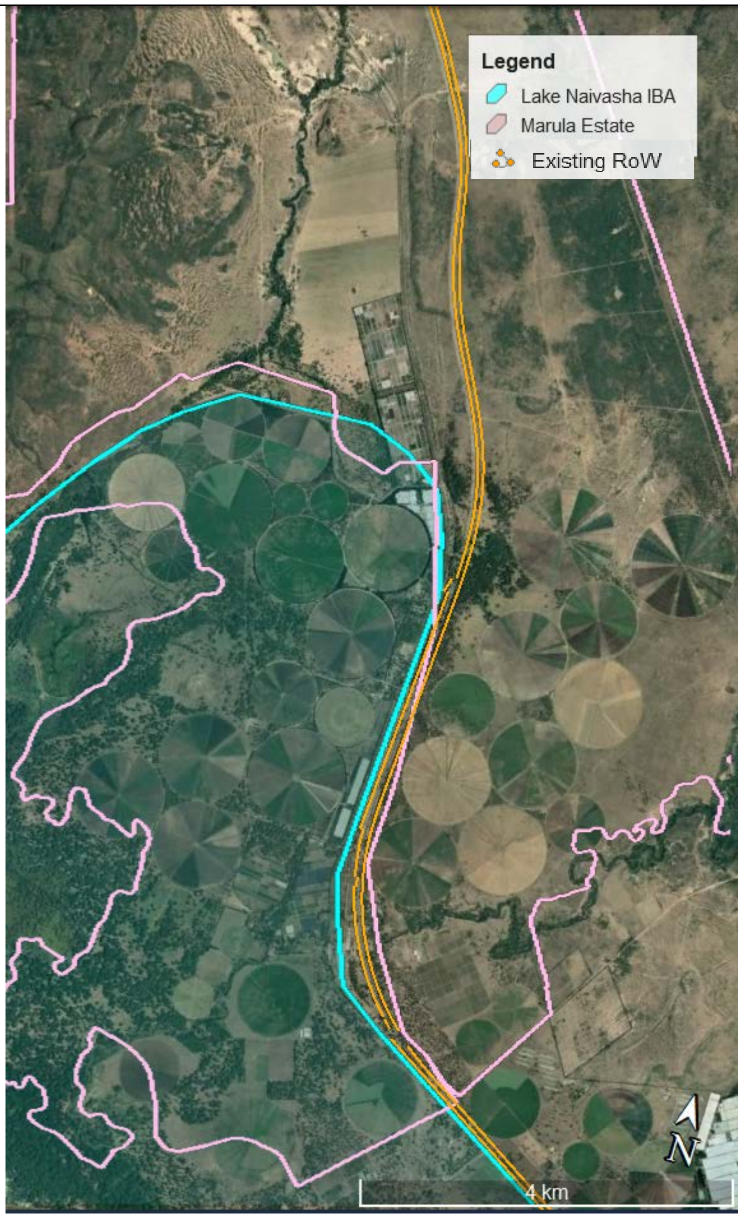
Kikuyu Escarpment Forest Reserve and IBA – A8 Section 1 (the road crosses the site along 9.2 km – Section 1 and 13.8 km along Section 5)

Kikuyu Escarpment Forest Reserve and IBA – A8South Section 5 (the road crosses the site along 9.2 km – Section 1 and 13.8 km along Section 5) – (Left=North; South=Right)

Naivasha Wildlife Training Institute Local Sanctuary (the RoW is adjacent to the site along about 3.0 km- section 1 A8, and about 1.3 km - section 6 A8South)



Soysambu Conservancy (the RoW crosses the site along about 7.7 km)



Marula Estate Conservancy (the RoW crosses the site along about 21.7 km) – (Left=North; South=Right)