Report on Avian and Plant Species Biodiversity Baseline Survey Conducted in the Northern Mara between 6th to 21st November 2024

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1.1 Acknowledgements

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This survey was conducted in the Northern Mara Conservancies by the following team: Oppenheimer Impact Scholar, Ms Milcah Kirinyet; Ornithologist, Mr John Musina; and Botanist, Mr Thomas Mwadime Nyange. The team received invaluable support from the Northern Mara Conservancies' management team and rangers, particularly Albert Cheruiyot and Dapash Francis, whose dedication and expertise greatly contributed to the success of this project. We thank Erick Odire for sharing the workflow that formed the basis of the habitat mapping analysis.

1.2 Executive Summary

This report presents a summary of a comprehensive survey that was conducted in the Northern Mara Conservancies to establish baseline data on avian and floral species composition. The survey aimed to provide a foundational understanding of biodiversity in the region, guiding conservation efforts and land use planning. This report presents key findings derived from the data collected.

The survey recorded a total of 412 floral species across the three conservancies, with Mbokishi having the highest diversity at 310 species, followed by Enonkishu with 203 species, and Olchoro Oirouwa with 196 species. Of these, 384 species are indigenous, while 28 are exotic, representing a small proportion of the total flora. The exotic species include naturalised, introduced ornamental, or alien invasive plants. Eight invasive plant species were recorded during the survey. Plant species listed in the IUCN Red List and CITES database were identified as conservation priorities.

A total of 187 bird species from 54 families were recorded. Twelve species were listed as threatened in the IUCN Red List. Among them,two vulture species, Ruppell's Griffon Vulture (*Gyps rueppellii*) and White-backed Griffon Vulture (*Gyps africanus*), are classified as **Critically Endangered**. Six species, including Secretarybird (*Sagittarius serpentarius*) and *Grey Crowned Crane* (*Balearica regulorum*), are classified as **Endangered**. One species, Tawny Eagle (*Aquila rapax*), is classified as **Vulnerable**, and two species, Crowned Eagle (*Stephanoaetus coronatus*) and Eurasian Roller (*Coracias garrulus*), are classified as **Near Threatened**.

1.3 Background

The Northern Mara Conservancies (Enonkishu, Olchoro Oirouwa, and Mbokishi) collectively span approximately 13,325 hectares, forming critical ecological zones within the larger Mara-Serengeti ecosystem, renowned for its rich biodiversity and complex ecological interactions. These areas serve as a vital interface between biodiversity conservation and community-based land management, demonstrating how sustainable practices can foster coexistence between wildlife and human activities.

Recent studies have further underscored the pivotal role of community conservancies in preserving wildlife populations within this region. A 2021 census revealed that over 80% of wildlife in the Maasai Mara were found in community conservancies, highlighting the growing importance of these areas as key players in biodiversity conservation and sustainable land management (Wildlife Research & Training Institute & Kenya Wildlife Service, 2021).

While these conservancies are recognized for their contributions to wildlife conservation, knowledge about other critical aspects of biodiversity remains limited. The avifauna of the Greater Mara Region is relatively well documented within the Maasai Mara National Reserve but knowledge about bird species in the surrounding conservancies is sparse. For instance, a 2016 study recorded 220 bird species at Mara Naboisho but noted that many species' distributions and habitat associations remain poorly understood, relying heavily on anecdotal evidence rather than systematic surveys (Monadjem & Virani, 2016). Although there are basic species lists available for the region, many of these lists do not capture the full complexity of avian and floral diversity across different habitats within the conservancies and the poorly contrained survey effort means that we cannot replicate the surveys to assess changes over time. This lack of detailed data can hinder evaluation of effective conservation strategies and management practices.

Extending baseline understanding through field surveys is particularly timely and significant for newer conservancies like Mbokishi that have not yet undergone extensive ecological assessments, further contributing to the data gap. This survey provides an essential opportunity to establish baseline data on its biodiversity, particularly focusing on avian and plant species, while considering the vital role of habitat in shaping the distribution and abundance of bird species.

This baseline survey builds upon the foundational work initiated by Biosphere Expeditions during their 2020 survey in Enonkishu (Lee et al., 2020), which documented over 230 bird species using the Southern African Bird Atlas Project (SABAP2) protocol, underscoring Enonkishu's role as a habitat for various avian populations, including endangered and migratory species. The findings emphasised the necessity for systematic monitoring to understand bird population dynamics and their interactions with land use patterns. The Biosphere Expeditions report from Enonkishu emphasised the critical need for systematic monitoring to better understand bird populations and their interactions with land use patterns. This indicates a broader gap in ecological data across these conservancies.

The Biosphere Expeditions report also laid the groundwork for understanding plant biodiversity through preliminary inventories. It highlighted the importance of grasslands and woodlands in sustaining habitat quality for both wildlife and livestock while revealing significant gaps in data regarding plant species composition, grassland health, and the prevalence of invasive species.

By creating a structured framework for systematic data collection, our survey addresses gaps identified in earlier research and recommendations to extend surveys to cover a larger geographical area, ensuring that future studies can compare data over time and assess trends effectively. Continuous monitoring through these transects is vital for assessing the health and resilience of the ecosystems within the conservancies. Long-term data will provide insights into species abundance, diversity, and habitat conditions, which are essential for informed conservation strategies and land management practices.

Central to the success and sustainability of this monitoring effort is capacity building, ensuring that local stakeholders are equipped with the necessary skills and knowledge to carry out long-term biodiversity monitoring independently. By fostering expertise in data collection, management, and interpretation, we strengthen local engagement and ownership of conservation efforts. This investment in skills development not only enhances the quality and reliability of ecological data but also ensures that monitoring remains an ongoing, community-driven process that supports adaptive conservation and land management strategies well into the future.

1.4 Introduction

The objectives of this survey were to:

- Establish a comprehensive biomonitoring baseline for avian and floral species composition in the Northern Mara Conservancies
- Optimise and expand the existing monitoring infrastructure, integrating bird and plant species alongside the ongoing mammal monitoring.
- Enhance local capacity to sustain ongoing biodiversity monitoring through training and knowledge transfer,incorporating the latest best practices in data management.
- Implement open source workflows, ensuring reproducibility, transparency, and efficiency.
- Align monitoring efforts with international standards and best practices for biodiversity monitoring and assessment.

We organised introductory sessions in Enonkishu (for both the Enonkishu and Mbokishi teams) and the Olchoro Oirouwa team at their office headquarters, to discuss the objectives of our visit and the importance of biodiversity surveys for the conservancies and develop the support of the teams and their participation in the planned activities.

1.5 Habitat Mapping and Site Selection for Biodiversity Monitoring

1.5.1 Habitat Stratification and Mapping

To ensure representative coverage of diverse habitats, the study area within the Northern Mara Conservancies was systematically stratified. Habitats were categorised into distinct types, including grasslands, shrublands, woodlands, and wetlands. Each stratum was treated as an independent unit for sampling. This stratified approach facilitated targeted data collection, ensuring that each habitat type was adequately represented in the study.

To map habitat types within the conservancies, we employed a combination of Google Earth Engine (GEE) and QGIS for data analysis and classification. The process began with the delineation of the area of interest (AOI), which encompassed the conservancies and an additional buffer zone. The buffer zone was incorporated to account for transitional land uses and edge effects, thus capturing a holistic picture of the landscape.

Landsat 8 Surface Reflectance imagery for the year 2023 was filtered to the AOI. To minimize noise from temporal variability, a median composite was generated, ensuring a representative snapshot of habitat conditions across the year.A cloud masking algorithm was applied to exclude pixels impacted by clouds and shadows, further enhancing the data quality. Vegetation indices, including the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), were calculated to improve the differentiation of land cover types.

To classify the habitat types, training data was prepared by merging feature collections that represented key habitats such as water, woodland, grassland, and shrubland. A Random Forest classifier was employed to classify the AOI, including the buffer zone, using spectral bands and vegetation indices. Model accuracy was validated through a split of training and testing datasets, ensuring reliability and robustness of the results. The final classified map was exported from GEE at a spatial resolution of 30 meters.

Further cartographic refinements, including symbology adjustments, legend additions, and layout enhancements, were implemented in QGIS to improve map readability and interpretation. The inclusion of the buffer zone provided insights into transitional landscapes surrounding the conservancies. This final map serves as a foundational resource for understanding habitat dynamics, guiding conservation planning, and informing land use decisions both within and beyond the conservancies.

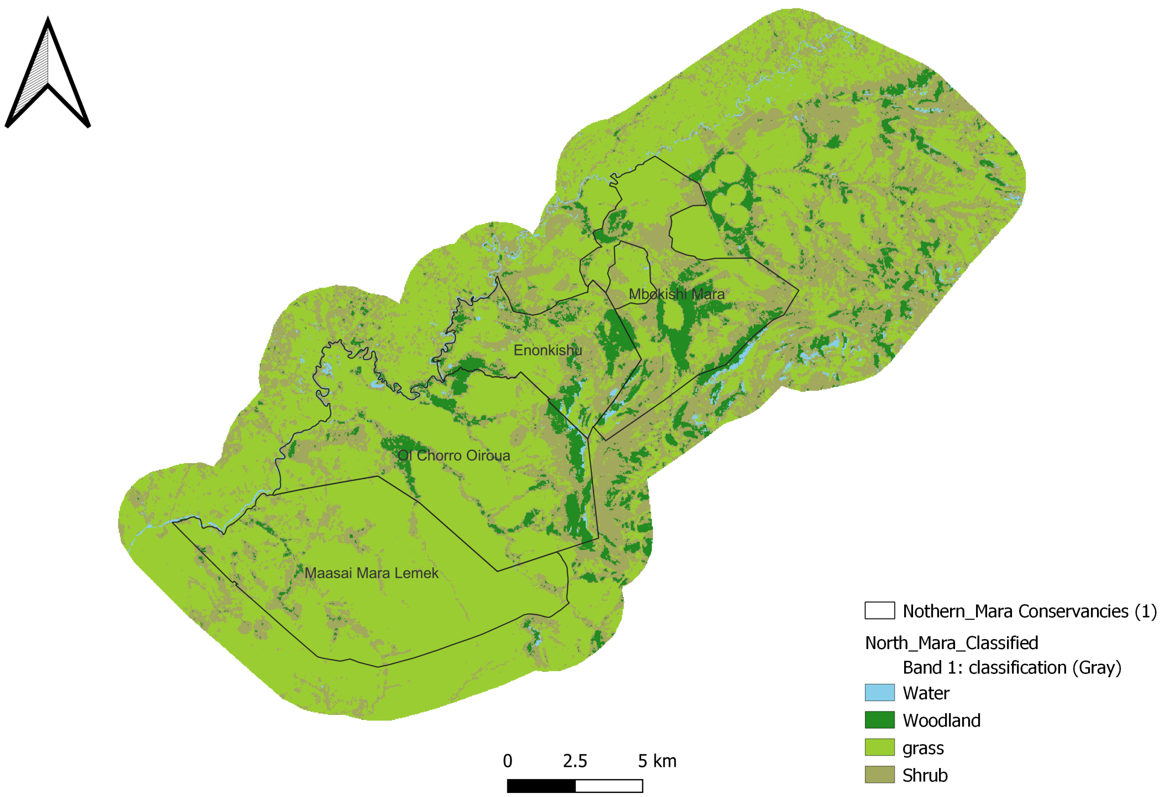

Figure 1. Northern Mara Conservancies' Habitat Types Map.

1.5.2 Survey Site Selection

Within the classified habitat strata, stratified random sampling was used to identify survey sites. This method ensured that key ecological features across habitat types were adequately represented, establishing a robust framework for biodiversity assessments. Selection of sampling sites was further refined using Google Earth Pro to pinpoint and mark precise locations for sampling points and transects across the landscape.

Monitoring sites were selected based on predefined criteria, ensuring comprehensive coverage of the ecological diversity within the conservancies. For bird surveys, line transects of approximately three kilometres were established for each habitat type, with at least two sites per habitat type in each conservancy. For vegetation monitoring, 1-kilometre transects were designed for each habitat type to adequately capture ecological variations across the landscape.

The refinement of site selection and monitoring strategies was significantly enhanced through close collaboration with local experts, including Albert Cheruiyot and Dapash Francis. Their extensive knowledge of the region's habitats was instrumental in capturing the ecological complexity and ensuring the accessibility of monitoring sites. This collaborative effort also facilitated the integration of ground truth data, reinforcing the spatial accuracy and ecological relevance of our sampling strategies.

1.6 Field Surveys

1.6.1 Avian Metrics

We used Point Counts on Line Transects to estimate the relative abundance and species diversity in three representative habitats namely; grassland, shrubland and forest. We also recorded opportunistic sightings to augment the species list of the general ecosystem. We covered a total of ten line transects, three in Enonkishu, three in Mbokishi and four in Olchoro Oirouwa conservancy. The transect were laid in three major habitat types; grassland, shrubland and forest.

1.6.1.1 Survey Design At the Point Counts, we worked on the maxim that if you stand at one point, it is possible to count all the birds seen and heard (Bibby *et al.*, 2000) . Point Counts were used to estimate the relative abundance and species diversity. Twelve Point Counts were performed at least once along a line transect laid in a grassland, shrubland or forest in the three conservancies. In addition, two Point Counts were conducted in Emarti settlement and farmlands and a farmland located at the eastern border of Mbokishi. All birds seen or heard were recorded at each census station located after every 200 m along the line transect. Also recorded were the number, behavior and its niche at the time of observation. In addition, simple habitat and environmental variables at the beginning of each count such as cloud cover (percentage of sky covered), wind (general direction), temperature (cold, warm or hot), and broad habitat type were recorded. The habitat type at each Point Count location was recorded.

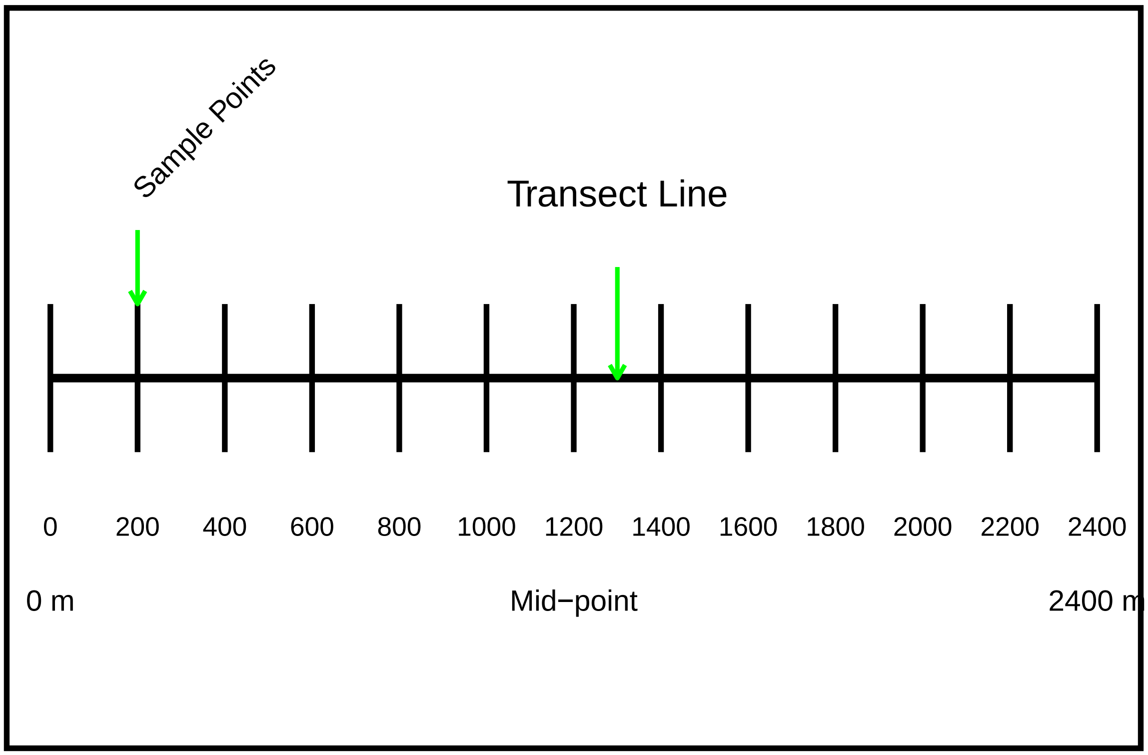

Figure 2. Transect line with sample points

1.6.1.2 Materials used

- Binoculars
- Spotting scope and sturdy tripod (for wietlands)
- Field data sheets and field notebook
- Clipboard, pencil and eraser
- Large clear plastic bag (envelop) to protect data sheets from rain
- GPS mobile field device/Compass
- Stopwatch
- Cameras (photographs)
- Taxonomic keys including;
  - Photo-Guides
  - Mobile Apps
  - Field Handbooks, especially:

1. Zimmerman, D. A., Pearson, D. J., & Turner, D. A. (1996). *Field guide to the birds of Kenya and northern Tanzania.* Princeton University Press.

2. Stevenson, T., & Fanshawe, J. (2002). *Birds of East Africa: Kenya, Tanzania, Uganda, Rwanda, Burundi.* Princeton University Press.

1.6.1.3 Opportunistic sightings We made observations for birds in different habitats found within the three conservancies. We made these observations at all times when not conducting Point Counts. From our base camp at Mara Training Center, we covered areas to the east towards Mbokishi and to the west towards Olchoro Oirouwa. We recorded species that we saw or heard and the habitat in which they occurred. For waterbirds, we looked for birds in both permanent and seasonal wetlands within the conservancies. We used these search data to expand the observed species list.

Figure 3. Sample images taken during observations in wetland areas.

1.6.1.4 Results

Overall, we recorded a total of **one hundred and eighty-seven** species of birds from fifty-four families. This list includes globally threatened species, long distance migrants and species that are partially or fully dependent on forest habitats. Twelve species were listed as threatened in the IUCN Red List. Two species of vultures, Ruppell's Griffon Vulture (*Gyps rueppellii*) and White-backed Griffon Vulture (*Gyps africanus*), are classified as **Critically Endangered**. Six species, including Secretarybird (*Sagittarius serpentarius*) and Grey Crowned Crane (*Balearica regulorum*), are classified as **Endangered**. One species, Tawny Eagle (*Aquila rapax*), is classified as **Vulnerable**, and two species, Crowned Eagle (*Stephanoaetus coronatus*) and Eurasian Roller (*Coracias garrulus*), are classified as **Near Threatened**.

We recorded forty-three migratory species from twenty-one families. Thirty-one were long-distance Palaearctic migrants. These included Black Stork (*Ciconia nigra*), European Honey Buzzard (*Pernis apivorus*), Willow Warbler (*Phylloscopus trochilus*) and Isabelline Wheatear (*Oenanthe isabellinus*). Eleven species, including Black-winged Stilt (*Himantopus himantopus*) and Squacco Heron (*Ardeola ralloides*), migrate within continental Africa.

Among terrestrial birds, fifty species from twenty-four families were forest birds. These included: Crowned Eagle (*Stephanoaetus coronatus*), Ayres's Hawk Eagle (*Aquila ayresii*) and Cinnamon-chested Bee-eater (*Merops oreobates*). We recorded a total of thirty-eight species of waterbirds from thirteen families. Some of them, such as Ruff (*Philomachus pugnax*) and Common Snipe (*Gallinago gallinago*), migrate from the Palaearctic region.

In all the three conservancies, most species were rare with a few common ones. The highest species diversity of grassland and forest birds was in Mbokishi, closely followed by Enonkishu. The highest species diversity of shrubland birds was in Enonkishu. Overall, species diversity was lowest in Olchoro Oirouwa for grassland, shrubland and forest birds.

We recommend a common habitat and species conservation strategy for the Enonkishu – Mbokishi – Olchoro Oirouwa ecosystem. As part of the strategy, there should be an integrated biodiversity monitoring framework involving conservancy scouts, biodiversity experts, wildlife managers, and local communities. In addition, the three conservancies can work with the relevant government agencies to make linear infrastructure such as electricity distribution lines and roads safe for birds and other wildlife.

1.6.1.4.1 Threatened Speciess

The IUCN categorizes species of birds through its Red List with the aim of assessing their conservation status and identifying which ones are most at risk of extinction. The IUCN Red List categories are widely understood for classifying species at risk of extinction globally. The Categories are; Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, Data Deficient and Not Evaluated. Species of birds that are classified as Critically Endangered, Endangered, Vulnerable or Near Threatened have shown evidence for rapid decline in their populations across their home range. We recorded 12 globally threatened species, with eight of them either Critically Endangered or Endangered.

Table 1: List of Bird Species and Their IUCN Status

Common Name	**Scientific Name**	**IUCN Status**	**Migratory Status**
Lesser Flamingo	*Phoeniconaias minor*	Near Threatened	Afrotropic Migrant (Note)
Secretarybird	*Sagittarius serpentarius*	Endangered	
White-backed Vulture	*Gyps africanus*	Critically Endangered	
Rüppell's Vulture	*Gyps rueppellii*	Critically Endangered	
Lappet-faced Vulture	*Torgos tracheliotus*	Endangered	
Bateleur	*Terathopius ecaudatus*	Endangered	
Tawny Eagle	*Aquila rapax*	Vulnerable	
Steppe Eagle	*Aquila nepalensis*	Endangered	Palaearctic Migrant
Martial Eagle	*Polemaetus bellicosus*	Endangered	
Crowned Eagle	*Stephanoaetus coronatus*	Near Threatened	
Grey Crowned Crane	*Balearica regulorum*	Endangered	
Eurasian Roller	*Coracias garrulus*	Near Threatened	Palaearctic Migrant

Note: Migrants may occur alongside resident, non-migratory individuals.

1.6.1.5 Forest dependent birds Forests are essential to birds because they provide shelter such as cavities for cavity-nesting birds such as woodpeckers and parrots, food such as insects and fruits for insectivores and frugivores and roosting places. Bennun *et al.* (1996) attempted to characterize the role of East African forests in avian conservation by categorizing birds found in our region according to the varying levels at which they depend on forests. They introduced three categories; FF or forest specialist, for those species that spent their entire life cycle in the forest interior, F or forest generalists, for species that are found both in the forest interior and at the edge and f or forest visitors, for species that visit forests but are not entirely dependent on it. We recorded at fifty (50) forest dependent species from twenty-four (24) families. Below is a list of forest specialists (FF) and forest generalists (F) recorded, out of which five (5) were birds of prey.

Figure 4. Forest dependent birds, Schalow's Turaco *Tauraco schalowi* and Cinnamon-chested Bee-eater *Merops oreobates*.

Table 2: List of Bird Species and Their Forest Dependency

Common Name	Scientific Name	Forest Dependency
European Honey Buzzard	*Pernis apivorus*	F
African Goshawk	*Accipiter tachiro*	F
Great Sparrowhawk	*Accipiter melanoleucus*	F
Ayres's Hawk Eagle	*Aquila ayresii*	F
Crowned Eagle	*Stephanoaetus coronatus*	FF
Tambourine Dove	*Turtur tympanistria*	F
Schalow's Turaco	*Tauraco schalowi*	F
Narina Trogon	*Apaloderma narina*	F
Cinnamon-chested Bee-eater	*Merops oreobates*	F
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	F
Black-backed Puffback	*Dryoscopus cubla*	F
Blackcap	*Sylvia atricapilla*	F
Ashy Flycatcher	*Muscicapa caerulescens*	F
African Dusky Flycatcher	*Muscicapa adusta*	F
Collared Sunbird	*Hedydipna collaris*	F

1.6.1.6 Migratory species Every year, millions of birds migrate across Africa. Nearly 200 species migrate regularly from Europe and Asia to Africa south of the Sahara (Bennun *et al.*, 1996; Harrison, 1997). They follow the East African – Eurasian flyway, a route with key stop over sites for waterbirds, land birds and birds of prey (BirdLife International, 2020; Lemoine, 2018). It is estimated that over 1.5 million birds from at least 37 families migrate through this flyway. In Kenya, out of the over 1100 species that occur here, at least 160 are classified as long-distance migrants from the Palaearctic region (Bird Committee, 2009; Zimmerman *et al.*, 1996). We recorded a total of forty-three (43) migratory species from 21 families. They include waterbirds such as the Black Stork (*Ciconia nigra*) and White Stork (*Ciconia ciconia*), landbirds such as Northern Wheatear (*Oenanthe oenanthe*) and Pied Wheatear (*Oenanthe pleschanka*) and birds of prey such as European Honey Buzzard (*Pernis apivorus*) and Montagu's Harrier (*Circus pygargus*). These species migrate from parts of northern Europe and Russia to Africa.

1.6.1.7 Waterbirds Wetlands are vital to birds, because just like forests, they provide food, shelter and nesting places. Wetlands are also important stop-over sites for migratory birds. We recorded a total of thirty-eight (38) waterbirds in the natural and man-made wetlands in the Enonkishu – Mbokishi – Ol Chorro ecosystem. Out of which sixteen (16) species migrate either within Africa or between Africa, Europe and parts of Asia.

1.6.1.8 Grassland and Shrubland birds The shrublands host both grassland and forest species and are important refuge for some species at times of resource scarcity when competition for food, nesting and roosting sites is intense in the forest and grasslands. We recorded a total of thirty-nine (39) species associated with grasslands, Mbokishi had thirty-nine (39) species, Enonkishu had thirty-seven (37) and Olchoro Oirouwa had thirty-one (31). Species with the highest relative abundance are congregatory species such as egrets that follow grazing herbivores, vultures that feed in groups or guineafowls that live in large social groups. The highest species diversity of shrubland birds was in Enonkishu. The diversity in Mbokishi and Ol Chorro was similar.

1.6.1.9 Discussion This ecosystem is a heterogeneous landscape with a diverse range of birds that also acts as an important stop-over and dispersal site for species that migrate within Africa (intra-African migrants) and out of Africa (long distance Palaearctic migrants).The presence of two Critically Endangered species of vultures and six Endangered species including the Grey Crowned Crane (*Balaerica regulorum*) elevates the regional and global role of this ecosystem as a key habitat in moderating populations of threatened avian species. In addition to habitat loss, populations of vultures and associated birds of prey continue to decline rapidly due to indiscriminate poisoning and collision with energy infrastructure. The Grey Crowned Crane on the other hand have suffered greatly from conversion of its wetland habitats into farmland.

Even though the three conservancies are at different stages of establishment in wildlife conservation, with Ol Chorro being the oldest and Mbokishi being the newest, this survey reveals significant species turn over across the three conservancies and their key habitats. Species with large home ranges such as Crowned Eagle (*Stephanoaetus coronatus*) and Martial Eagle (*Polemaetus bellicosus*), may nest in one conservancy but disperse elsewhere to feed. Therefore, it would be ecologically ineffective to conserve the nesting sites of such a species without doing the same in its feeding sites.On the other hand, both the natural and artificial wetlands are important roosting sites for species such as Cattle Egrets (*Egretta garzetta*) that follow grazing herbivores in the grasslands to feed on flushed insects and other invertebrates. In addition, in the dry season, most resident and migratory waterbirds congregate at these wetlands.

1.7 Vegetation Metrics

1.7.1 Vegetation classification

The study area's plant cover is predominantly secondary in nature and consists of three main vegetation types; shrubland, grassland and forest, other microhabitats include different wetland types such as seasonal and permanent water pools/marsh and seepages.

1.7.1.1 Shrubland The study area comprise of three main shrubland types namely; Semi-evergreen shrubland dominated by *Tarchonanthus camphoratus*, *Psiadia punctulata*, *Euclea spp.*, *Croton dichogamus* and *Searsia crenulata* that is edaphically restricted to rocky hill slopes and grassy hill bases and generally representing the climax vegetation. Secondary evergreen shrubland dominated with *Euclea divinorum* is the vegetation type that forms the ecotone between upland evergreen dry forest patches and open grasslands, *Croton dichogamus* dominated semi-evergreen shrubland/thicket forming at edges of *Tarchonanthus* shrubland and upland dry forest is a sign of high degradation. All these habitats had variations in species composition observed at different sample points, these variations were greatly influenced by edaphic, climate, weather (Abiotic factors) and human, livestock and wildlife (Biotic factors).

1.7.1.2 Grassland Grasslands consist of vast areas dominated mainly by grass and in our study area are generally secondary in nature due to past human interference mainly for settlement, crop land and livestock pasture lands and also co-existing with wildlife. Variations in species composition was observed at different sampling areas resulting in four categories of grassland types namely; wooded grassland with *Balanites aegyptiaca* as the dominant trees, bushed grassland with *Euclea divinorum* or *Tarchonanthus* as the main bushes, open scattered tree grassland with *Balanites aegyptiaca* and *Vachellia gerrardii* as the main trees while *Sporobolus pyramidalis* and *Themeda triandra* as dominant grass species and "fallow land" is a secondary grassland type represented by the recently abandoned croplands for the purpose of wildlife conservation with very short grass and consist of overgrazed land dominated with *Chloris pycnothrix*, *Cynodon dactylon*, *Digitaria abyssinica*, *Trifolium semipilosum*, *Solanum campylacanthum* and *Dyschoriste radicans* and many naturalized exotic weed species.

1.7.1.3 Forest This vegetation type consists of an assemblage of trees with a continuous interlocking canopy and constitutes about 10-20% percent of the study area. This plant community was identified as Upland evergreen dry forest and is mainly dominated by *Diospyros abyssinica*, *Euclea divinorum* and *Warburgia ugandensis* as the upper canopy species while *Croton dichogamus* as the dominant understory shrub, variations in species composition was observed with increase in moisture and edaphic factors. The moistier type consisted of *Diospyros abyssinica* and *Warburgia ugandensis* as the dominant upper canopy species with *Justicia spp.* as the under story herb species while the much drier type consisted of *Olea* and *Diospyros* as dominant upper canopy species and *Hypoestes forskaolii* and *Setaria megaphylla* as the dominant herbaceous species.

1.7.1.4 Wetlands These are permanently or seasonally wet grounds that constitute plant assemblages with unique plants that are adapted to waterlogged environments. These form part of the microhabitats that include different wetland types such as seasonal and permanent water pools/marsh, man-made dams and seepages.

1.7.2 Survey Design

Plant diversity documentation entailed establishment of 1 km line transects, each containing five sampling plots measuring 20 x 20 meters, spaced 250 m apart from their center points. This resulted in a total of 55 sampling plots within the conservancies and an additional four control plots outside the conservancies. The transects were distributed as follows: three in Enonkishu, four in Mbokishi, and four in Olchoro Oirouwa conservancies. In addition to these, specific microhabitats such as wetlands were targeted for sampling, where five wetlands were surveyed without establishing fixed plots.

Tree sampling included identifying and counting all trees within the 20 x 20 m plots, along with estimating canopy cover and tree height. Shrubs were sampled within one 10 x 10 m subplot nested in the larger plot, while herbaceous plants were sampled using four 1 x 1 m quadrats, placed at the 5-meter points in randomly selected directions (north, south, east, or west) from the center. The sampling plots captured data on plant species diversity, composition, and abundance, including records of dominant trees, shrubs, and herbs, individual species counts, and estimates of average height and cover. These attributes were used to classify different vegetation types.

Additional plant documentation was conducted outside the established sample plots to provide a comprehensive understanding of the ecosystem. A handheld GPS was used to georeference all sample plots/points and record elevation. Species of conservation concern, including rare and threatened plants, were identified using information from the International Union for Conservation of Nature (IUCN) and the Convention on International Trade in Endangered Species (CITES) databases. Photographs were taken for further identification and reporting, and plant specimens were collected for identification and preservation at the East African Herbarium.

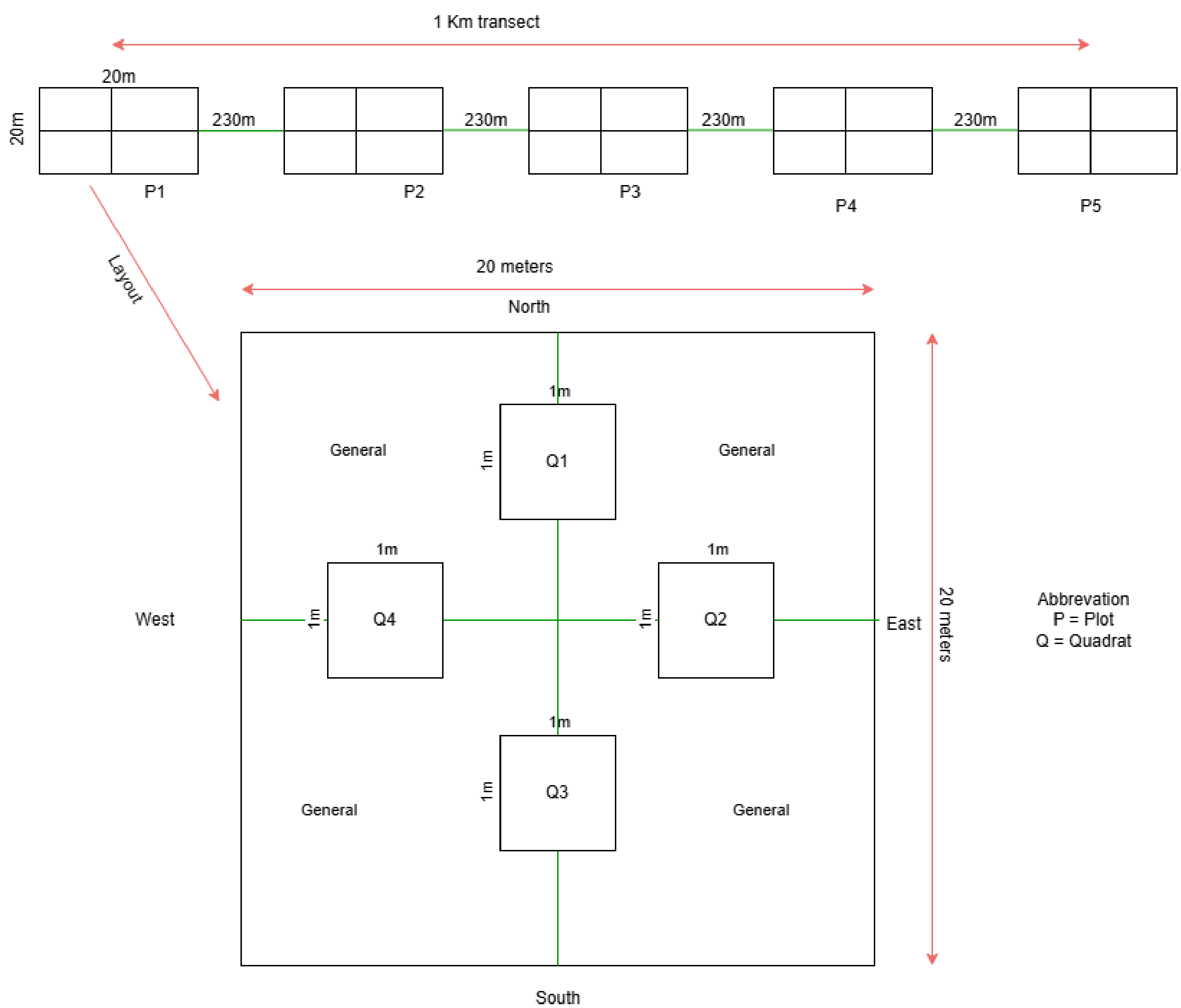

Figure 5. Transect plots and quadrats setup

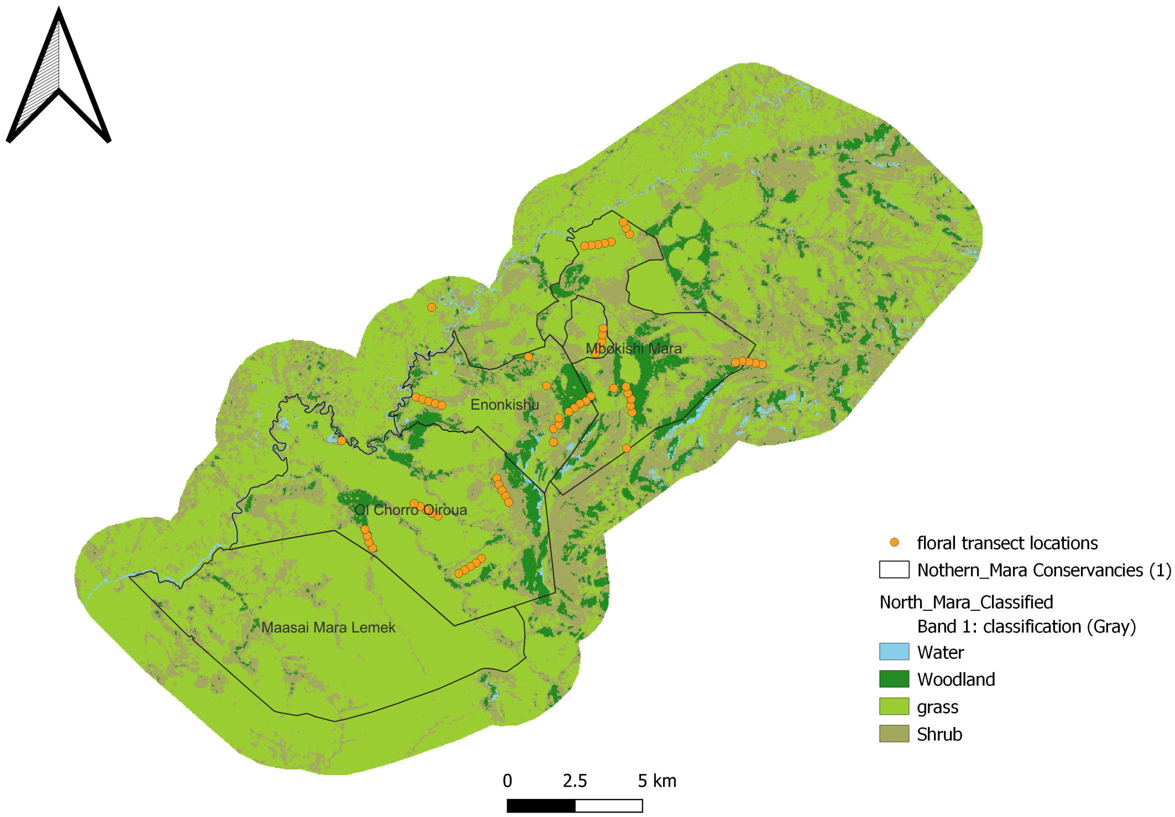

Figure 6. Established floral transect locations

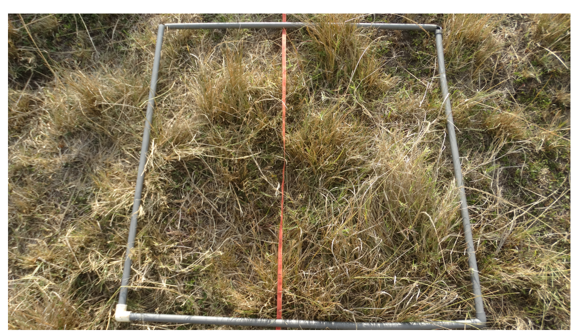

Figure 7. Photographs taken during vegetation sampling.

1.8 Results/Findings

1.8.1 Floral Species diversity and composition

A total of 412 plant species belonging to 71 families and 268 genera were recorded during the survey. Out of the total species recorded 384 were indigenous and 28 were exotic including naturalized weeds, invasive, introduced ornamentals or hedge plants. Poaceae (Grass family) had the highest diversity with 63 species followed by Asteraceae (Sunflower family) with with 46 species, Fabaceae (Legume family) with 43 species, Acanthaceae (Acanthus family) with 25 and Malvaceae (Cotton family) with 21 species, all the five families representing about 48% of the total species. The genus *Cyperus* was the most diverse with 13 species then followed by *Indigofera* with 9 species, then *Vachellia* and *Eragrostis* both with 8 species each.

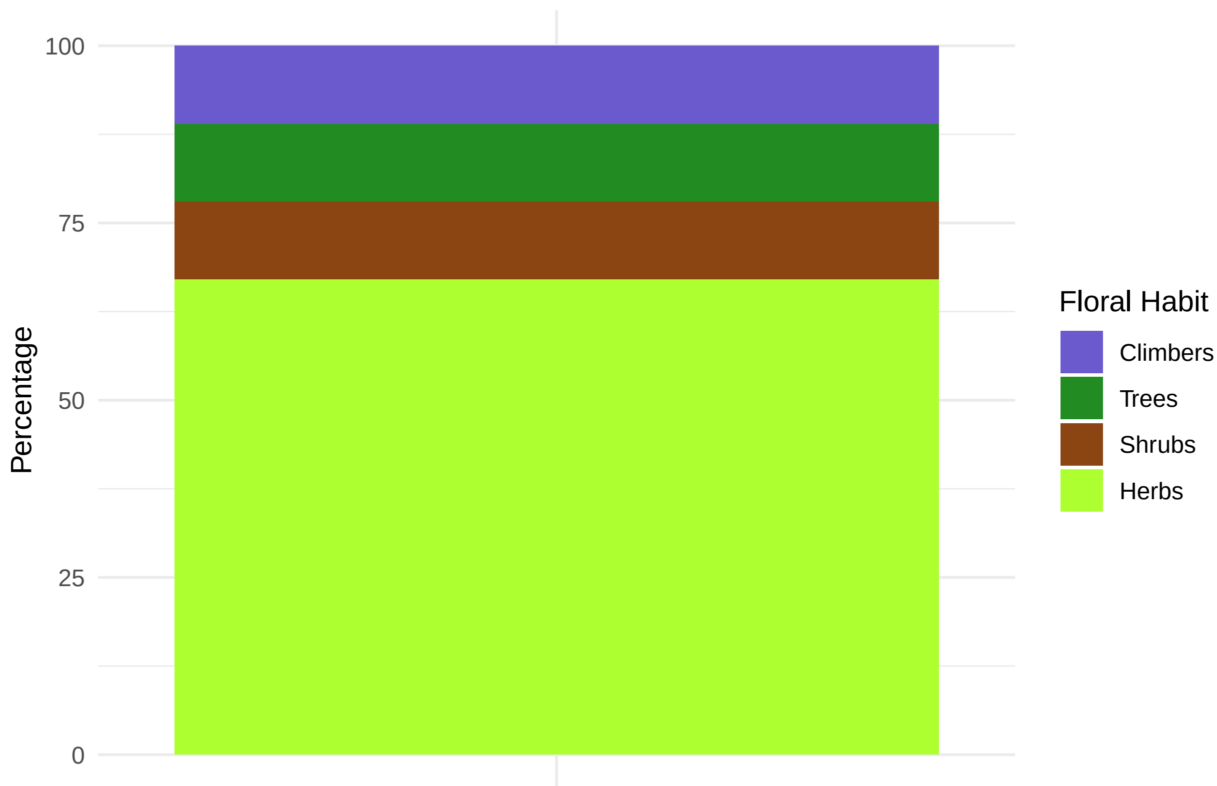

Figure 8. Floral Habit Diversity as a Percentage.

1.8.2 Invasive species

These are introduced non-native or native plants that adversely affect the habitats they invade economically, environmentally and ecologically. Eight invasive plants were recorded during the survey.

Table 3: List of Invasive Species and Their Habit.

Family	**Species**	**Habit**
Asteraceae	*Parthenium hysterophorus* L.	Herb
Asteraceae	*Senecio madagascariensis* Poir.	Herb
Asteraceae	*Xanthium strumarium* L.	Herb
Cactaceae	*Austrocylindropuntia subulata* (Muehlenpf.) Backeb.	Shrub
Cactaceae	*Opuntia ficus-indica* (L.) Mill.	Shrub
Fabaceae	*Caesalpinia decapetala* (Roth) Alston	Shrub
Solanaceae	*Datura stramonium* L.	Herb
Verbenaceae	*Lantana camara* L.	Shrub

(a) *Caesalpinia decapetala*

(b) *Parthenium hysterophorus*

(c) *Senecio madagascariensis*

(d) *Austrocylindropuntia subulata*

Figure 9. Photographs of invasive species observed during the Northern Mara biodiversity survey.

1.8.3 Species of Conservation Concern

This section documents species identified during the survey that are listed under globally recognized conservation frameworks, namely the IUCN Red List and CITES Appendices.

Table 4: List of IUCN Red List Species, Their Habits, and Respective Categories

Family	Species	Habit	IUCN Category
Asphodelaceae	*Aloe lateritia Engl. var. graminicola*	Herb	Least Concern (LC)
Asphodelaceae	*Aloe volkensii Engl. ssp. multicaulis*	Tree	Least Concern (LC)
Euphorbiaceae	*Euphorbia bicompacta Bruyns var. bicompacta*	Tree	Least Concern (LC)
Euphorbiaceae	*Euphorbia candelabrum Kotschy*	Tree	Least Concern (LC)
Euphorbiaceae	*Euphorbia magnicapsula S.Carter var. magnicapsula*	Tree	Near Threatened (NT)
Santalaceae	*Osyris lanceolata Hochst. & Steud.*	Shrub	Least Concern (LC)

- Six species recorded during the survey fall under the Least Concern (LC) and Near Threatened (NT) categories (Table 2).
- *Euphorbia magnicapsula var. magnicapsula*, categorized as NT, requires attention due to its proximity to higher risk levels of extinction.


Figure 10. From left; *Aloe lateritia var. graminicola* and *Euphorbia magnicapsula var. magnicapsula*, both species listed under the IUCN Red List.

Table 5: List of CITES Species, Their Habits, and Categories

Family	**Species**	**Habit**	**CITES Appendix**
Asphodelaceae	*Aloe lateritia Engl. var. graminicola*	Herb	Appendix II
Asphodelaceae	*Aloe volkensii Engl. ssp. multicaulis*	Tree	Appendix II
Euphorbiaceae	*Euphorbia candelabrum Kotschy*	Tree	Appendix II
Euphorbiaceae	*Euphorbia magnicapsula S.Carter var. magnicapsula*	Tree	Appendix II
Orchidaceae	*Aerangis confusa J.Stewart*	Herb	Appendix II
Orchidaceae	*Aerangis luteoalba (Kraenzl.) Schltr. var. rhodosticta*	Herb	Appendix II
Orchidaceae	*Cyrtorchis praetermissa Summerh.*	Herb	Appendix II
Santalaceae	*Osyris lanceolata Hochst. & Steud.*	Shrub	Appendix II

- Eight species recorded are included in Appendix II, indicating the need for regulated trade to prevent their overexploitation (Table 3).
- Notable examples include *Osyris lanceolata*, which faces pressures from commercial harvesting, and orchids like *Aerangis confusa*, known for their ornamental value.

Figure 11. From left; *Aerangis confusa*, an epiphytic orchid, and *Osyris lanceolata* (African Sandalwood), species protected under CITES Appendix II.

1.8.4 Threats to the vegetation

- Past clearing of indigenous forest to clear way for development was observed at Mbokish Conservancy settlement area and was evident due to presence of several tree stamps of *Olea europaea* and secondary bushes dominated by *Croton dichogamus* and *Euclea spp.*
- Overgrazing by livestock was evident at Mbokishi conservancy settlement areas near bomas as indicated by the relatively high proportion of bare ground observed.
- Improper disposal and introduction exotic hedge plants without expert consultation is leading to invasion into the natural vegetation thus interfering with the native species composition was observed at Enonkishu conservancy.
- Invasion of by the alien invasive species such as *Parthenium hysperophorus* and *Lantana camara* was observed.

Figure 12. Tree stumps evidencing past clearing of indigenous forest.

1.8.4.1 Discussion

A total of 412 species were recorded during the survey. A total of 384 are indigenous and 28 are exotic which represents a small fraction of the total flora which are either naturalized, introduced ornamentals or alien invasive species constituted less than 10% of the total plants recorded. The plant diversity is considered significant despite the fact that most of the study area has undergone some form of habitat degradation.

Mbokishi had highest diversity due to most of its vegetation is secondary in nature especially recently abandoned cropland with very high diversity of naturalized exotic weeds, the permanent wetland at Chali Chali base camp also highly contributed to its diversity whereas Enonkishu and Olchoro Oirouwa had great similarity with more homogenous old grasslands, with shrublands and forests forming climax vegetation. Poaceae (Grass family) had the highest diversity with 63 species followed Asteraceae (Sunflower family) with 46 species then Fabaceae (Legume family) by with 43 species, Acanthaceae (Acanthus family) with 25 species and Malvaceae (Cotton family) with 21 species, all the five families representing about 48% of the total species and thus playing a very important role in understanding the role they play in this important ecosystems and adjacent environs. The vegetation diversity and composition across most of the habitats sampled was highly dependent on human interference, most of the present vegetation is as result of secondary regeneration after the original forests were cleared to clear way for settlement, crop cultivation and livestock keeping. Its vegetation is host to several CITES species and its preservation will ensure protection of these important species of flora and fauna it hosts and the entire ecosystem. The established sample plots will be used to monitor plants diversity and composition dynamics over time.

1.8.5 Conclusion and Recommendations

The areas biodiversity is highly dependent on human intervention and natural factors such as edaphic and climatic conditions. This survey reveals significant species turn over across the three conservancies and their key habitats. High species diversity is expected after subsequent surveys and expert consultations. There will be more benefit in establishing research partnerships.

- It is highly recommended that the three conservancies prepare and adopt the same conservation strategy or biodiversity action plan to guide in their management to maximise efficiency savings and mutual benefit. In this plan, we recommend robust species and habitat conservation strategies using threatened species as flagships.
- As a baseline, this survey provides a platform for establishment of an avian monitoring program. This program can make use of the already set line transects in the grasslands, shrublands and forests.
- For a robust avian monitoring program to sustain, the conservancy scouts will require training in fundamentals of ornithology, precisely on bird identification, field data collection and basic data analysis and curation. The training expertise can be provided by institutions such as the Ornithology Section of the National Museums of Kenya.
- It is urgent that the conservancies make linear infrastructure such as electricity distribution lines and roads safe for birds. For instance, the electricity distribution lines can be retrofitted accordingly to prevent electrocution of perching birds of prey. Most of the threatened species found within these three conservancies are medium to large – sized birds of prey of waterbirds. This group of birds is prone to electrocution, especially birds of prey that perch on electricity poles as vantage point from which can locate prey.
- Strategically planned development in the conservancies to reduce damage to vegetation.
- Proper disposal of exotic hedge plants to avoid invasion into the natural habitat by uprooting and incineration.
- Reduce introduction of exotic ornamental species by using indigenous plants for landscaping which should be guided by plant experts.
- Manage the spread of invasive species such as *Lantana camara* (Tick Berry) by physical removal, being proactive about this will yield long term savings.

1.9 Training and Capacity Building

To enhance the capacity-building efforts for ground teams, we convened a half-day training for the rangers, to equip the rangers with the necessary skills and knowledge on transect set up protocols, data and tools used in both avian and plants species monitoring. During this training, we covered fundamental topics, including:

- Transect setup: Detailed instructions on how to establish transects for both bird surveys and vegetation monitoring were demonstrated including other methods that were not used in this survey (e.g., mist nets).
- Identification Skills: Rangers were trained in identifying birds using various features such as size, shape, plumage, sounds, calls, behaviour, and habitat preferences. This skill is vital for accurate identification of species in monitoring and data collection.
- Guiding Books: Participants were introduced to various reference materials available for bird identification and habitat assessment, enhancing their resources for ongoing learning.
- An important addition to the training was the linking of monitoring to global standards like IUCN, rangers were taken through how to check the IUCN Red List for assessing the conservation value of species identified in their areas. Understanding the status of species is crucial for prioritising conservation actions and monitoring efforts.

The training underscored the significance of biodiversity monitoring in maintaining healthy ecosystems. By equipping rangers with these skills, we aim to foster a culture of continuous learning and engagement that enhances their effectiveness in conservation work. A list of participants is provided in the appendix for reference.

Figure 13. Photos taken during the training sessions.

1.10 Appendix I

1.10.1 Data and code availability

All raw data, analysis scripts, and supplementary materials from this research are openly available in our dedicated GitHub repository:

https://github.com/TESS-Laboratory/northern-mara-biodiversity-survey/tree/main

1.10.2 Data forms

The front pages of the data Sheets used during the study are shown below:

Avian Survey: Point Counts

TRANSECT SAMPLING (POINT COUNTS)			**Date:**		**Start Time:**		**End Time:**		**Transect Name:**	
Start Co-ords:			**End Co-ords:**					**Cloud Cover:**		
Rain:		**Fog:**	**Temp:**		**Wind:**		**Wind direction:**			
General Habitat:										
Observers:										
No.	**Time**	**Species Name**	**Dist.**	**No.**	**Height**	**Niche**	**Behavior**	**Elevation**	**Vegetation**	**Notes (sex, flight path etc)**

Figure 14. Front page of the Avian Point Count Data Sheet

Vegetation Sampling Data Sheet

Recorder:	GPS Coordinates	Date:
Transect No: Plot No:	Latitude:	Orientation:
Alt:	Longitude:	Photo No:

Habitat description:

Vegetation Cover (%)		Average Height (m)	Dominant Species
Trees			
Shrubs			
Herbs			

Trees (20m x 20m)			Shrubs (10m x 10m) Sub plot		
Species	Qty	H(m)	Species	Qty	H(m)

Figure 15. Front page of the Vegetation Sampling Data Sheet

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