REPUBLIC OF KENYA

NATIONAL ECOLOGICAL MONITORING FRAMEWORK FOR KENYA'S WILDLIFE RESOURCES

WILDLIFE RESEARCH AND TRAINING INSTITUTE

DECEMBER 2025

(Wildlife Sector Operational Manual)

OFFICIAL STATUS

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LIST OF ACRONYMS

Acronym **Meaning**

ASTER - Advanced Space borne Thermal Emission and Reflection

AWF - African Wildlife Foundation

CBD - Convention of Biological Diversity

CITES - Convention on International Trade in Species

CMR - Capture-Mark-Release

CMS - Convention on Migratory Species

CNI - Cumulative Number of individuals

CNS - Cumulative Number of Species

CRS - Certificate of Release of Service

CORDIO - Coral Reef Degradation in Indian Ocean

DEM - Digital Elevation Model

DRSRS - Department of Resource Survey and Remote Sensing

EA - Environmental Audit

EAWLS - East African Wildlife Society

EIA - Environmental Impact Assessment

EMCA - Environmental Management and Coordination Act

EPA - Environmental Protection Agency

ERDAS - Earth Resources Data Analysis Systems

FAR - Fecal Accumulation Rate

Acronym **Meaning**

FIRMS - Fire Management Information Systems

FSO- Front Seat Observer

FTD - Fly per Trap per Day

GDEM - Global Digital Elevation Model

GHCN - Global Historical Climatology Network

GIS - Geographic Information Systems

GPCP - Global Precipitation Climatology Project

GPS - Global Positioning System

HFI - Human Footprint Index

IBA - Important Bird Areas

ICIPE - International Center of Insect Physiology and Ecology

IFAW - International Fund for Animal Welfare

IGBP - International Biosphere Program

IPR - Intellectual Property Rights

IUCN - International Union for Conservation of Nature

KARI - Kenya Agricultural Research Institute

KEFRI - Kenya Forestry Research Institute

KEMFRI - Kenya Marine and Fisheries Research Institute

KENTTEC - Kenya Tsetse and Trypanosomiasis Eradication Council

KFS - Kenya Forestry Service

KNARL - Kenya National Agricultural Research Laboratory

KWS - Kenya Wildlife Service

LULC - Land Use-Land Cover

MCA - Mountain Conservation Area

MIST - Management Information System

MEAs- Multilateral Environmental Agreements

MODIS - Moderate-resolution Imagery Spectrometer

NASA - National Aeronautics and Space Administration

NBSAP - National Biodiversity Action Plan

NDVI- Normalized Difference Vegetation Index

NEMA - National Environmental Management Authority

NGO - Non-Governmental Organization

NMK - National Museums of Kenya

PAC - Problem Animal Control

PDA - Personal Digital Assistant

PTT- Platform Transmitter Terminal

RAI- Relative Abundance Index

RAM - Random Access Memory

RSO - Rear Seat Observer

SEDAC- Socio-Economic Data and Applications Centre

SoK- Survey of Kenya

SOP- Standard Operating Procedure

TANAPA - Tanzania National Parks

TAWIRI - Tanzania Wildlife Research Institute

TDS - Timed Direct Search

TLS - Time Limited Search

UNCC - United Nations Convention on Climate Change

UNEP - United Nation Environmental Program

UNFCCD - United Nations Framework on Climate Change and desertification

UTM - Universal Transverse Mercator

WRTI - Wildlife Research and Training Institute

WD - Wildlife Division

USAID - United States Aid for International Development

WARMA - Water Resources Management Authority

WTO - World Trade Organization

ZSL - Zoological Society of London

Definitions

1. Ecological assessment

Ecological assessment refers to a comprehensive assessment of the entire area potentially affected by development or proposed at a mitigation site. An ecological assessment includes an evaluation of both the biotic and abiotic components of an ecosystem. A major objective of biodiversity assessments is to inform policies that seek to reduce the rate of biodiversity loss as part of a sustainable development strategy. The results of the assessment should be used to update and improve on the underlying model of the system as a basis for future research and management.

2. Ecological monitoring

Ecological monitoring is the quantitative assessment of the status and trends in the structure and dynamics of ecosystems or its components. It is a programme that involves surveys or measurements, analysis and reporting normally adopting standardized procedures. These include observation of processes and indicators that show changes in ecosystem dynamics and structures, leading to the knowledge of how ecosystems work, and how they may be managed. Data may be collected on a variety of selected ecological indicators on vegetation, soils, hydrology, or broader themes such as biodiversity and socio-economics. Monitoring data helps to define the normal limits of natural variation in the conservation area resources and provide a basis for understanding observed changes and possible management interventions.

EXECUTIVE SUMMARY

The Wildlife research and Training Institute (WRTI), working with key stakeholders, has developed a National Ecological Monitoring Framework, which sets out a Protocol for Ecological Monitoring Activities in Wildlife Conservation Areas. The Framework provides standardized guidelines, methodologies and schedules for ecological assessments and long-term wildlife monitoring nationwide. By establishing common protocols and a coordinated monitoring calendar, it aims to improve the quality, consistency and comparability of data across institutions, strengthen the evidence base for wildlife policy and management decisions, and enable comparison with historical data to project future trends.
This Framework is aligned with the Constitution of Kenya (2010), the Wildlife Conservation and Management Act (2013), the Environmental Management and Coordination Act (1999), the National Wildlife Strategy 2030, the National Biodiversity Strategy and Action Plan (2019–2030), the Kenya National Wildlife Census Guidelines, and the relevant international conventions to which Kenya is a party.

It addresses both the spatial and temporal dimensions of ecological monitoring, focusing on the natural and human induced drivers of wildlife population decline, local extirpation, habitat degradation and species extinction, in order to promote a fuller understanding of ecological trends and their causes. In view of financial, technical and human resource constraints, the Framework adopts a strategic and selective approach, prioritizing the indicators and monitoring elements of greatest conservation and management value. It also outlines recommended monitoring designs, methodologies and population sampling techniques for different ecological contexts.

The key protocols highlighted in this report include:

1. Ecological Assessment Framework
2. Wildlife Censuses (Total aerial census, Sample aerial census, total ground census, sample ground census, marine census, waterfowl counts)
3. Monitoring Protocol for Forest Elephants- dung-count based methods, fecal-DNA based method,
4. Monitoring Protocols for Large Carnivores
5. Monitoring Protocol for non-human Primates
6. Monitoring Protocol for Water and terrestrial Birds
7. Monitoring Protocol for Reptiles and Amphibians
8. Monitoring Protocol for Terrestrial and Aquatic Invertebrates
9. Hydrological monitoring
10. Monitoring Protocol for Fresh Water Fish Species
11. Monitoring Protocol for Weather
12. Monitoring protocol for Marine Wildlife, macroinvertebrate Assessments
13. Data management and analysis

PREFACE

The Ministry of Tourism and Wildlife, in collaboration with wildlife conservation agencies and stakeholders, has developed an updated Standard Ecological Manual for Kenya's wildlife resource. The manual provides a clear strategy and standardized, scientifically sound protocols for long-term ecological monitoring, presented in a user-friendly format. By promoting systematic and reliable data collection, the manual enables information gathered at site level to be aggregated to landscape and national scales, in line with the Constitution, relevant policies, legislation, and institutional mandates of the Ministry, WRTI, and KWS.

The establishment of national parks and other conservation areas is aimed at safeguarding biodiversity through sustainable management. Effective conservation requires a continuous management planning process in which plans are implemented, monitored, reviewed, and revised based on observed outcomes. Ecological monitoring is therefore central to adaptive management, ensuring that conservation actions are informed by evidence on biodiversity status and trends.

Wildlife management in Kenya faces increasing challenges, including inadequate and fragmented data to support effective policy, legislation, and management decisions. Conservation managers require comprehensive and reliable information to address complex issues, coordinate with other agencies, and communicate conservation needs to the public. Standardized ecological monitoring is also essential for sustaining ecosystem services that support community livelihoods, social stability, and harmony.

With the establishment of WRTI and its research mandate, there was a need to review and harmonize earlier monitoring protocols developed by KWS and to expand their application across all land uses and conservation actors. The participatory development of this manual ensures a coordinated national approach aligned with the National Biodiversity Strategy and Action Plan and Kenya's obligations under the Convention on Biological Diversity. The manual provides a robust framework for data collection, analysis, and reporting across institutions, generating critical information to assess threats, guide policy and legislation, support national reporting, and contribute to the achievement of Kenya's Vision 2030 goals.

Hon. Rebecca Miano, EGH
Cabinet Secretary
Ministry of Tourism and Wildlife

FOREWORD

Biodiversity conservation is fundamental to human survival, economic development, and well-being, providing essential goods and ecosystem services such as food, medicine, raw materials, and livelihoods. In Kenya, wildlife is the backbone of the tourism sector and a key contributor to the economic pillar of Vision 2030, while the richness and beauty of biodiversity greatly enhance quality of life.

Kenya faces serious challenges in maintaining the integrity of wildlife habitats, with rapid loss of natural capital resulting in significant economic costs and dramatic declines in wildlife populations, particularly in rangelands. Changing land-use patterns have more than halved the wildlife populations over the past four decades, underscoring the urgent need for regular, reliable biodiversity monitoring to inform sound decision-making, policy formulation, and effective conservation and management strategies.

In response, the Wildlife Research and Training Institute, in partnership with stakeholders, has developed a standardized Ecological Monitoring Manual to support routine, science-based biodiversity monitoring nationwide. This manual provides a critical foundation for assessing the status and trends of natural resources, strengthening environmental governance, fulfilling Kenya's obligations under the Convention on Biological Diversity, and supporting the implementation of the National Biodiversity Strategy and Action Plan and global biodiversity targets.

Silvia Museiya, CBS

Principal Secretary
Ministry of Tourism and Wildlife
State Department for Wildlife

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We sincerely acknowledge the valuable input of scientists drawn from the National Museums of Kenya, Kenya Wildlife Service, non-governmental organizations, and private individuals. Their expertise, commitment, and time were instrumental in strengthening the scientific rigor of the manual and in the development of several unique and specialized protocols.

The coordination of the manual's development was effectively led by the Institute, and we extend our appreciation to all staff involved for their dedication, professionalism, and collective effort in bringing this important initiative to fruition.

DR. PATRICK OMONDI, OGW
DIRECTOR/CEO
WILDLIFE RESEARCH AND TRAINING INSTITUTE

1.0 Introduction

Kenya's wildlife resources are of outstanding national, regional, and global importance, underpinning biodiversity conservation, ecosystem services, tourism, livelihoods, and cultural heritage. Despite its relatively small land area of 581,677 km², the country supports exceptional biological diversity across all major ecosystems, ranging from coastal and marine systems to high-altitude montane environments. Kenya hosts disproportionately high numbers of plant and animal species, including significant levels of endemism and threatened species, placing it among the world's most biologically rich nations and reinforcing the strategic importance of conserving its natural heritage.

However, Kenya's wildlife and habitats are facing escalating and interconnected threats. Habitat loss, degradation, and fragmentation driven by unplanned land-use change, agricultural expansion, infrastructure development, and increasing human and livestock populations remain the primary pressures. These are compounded by poaching and illegal wildlife trade, invasive alien species, pollution, overexploitation of natural resources, climate variability and change, and wildlife diseases. The National Wildlife Census 2025 confirms that wildlife populations and habitats are declining at an accelerating rate, highlighting the urgent need for coordinated, data-driven, whole-of-government interventions to reverse these trends.

The loss of biodiversity has far-reaching ecological and socio-economic consequences. Degraded ecosystems compromise critical services such as water regulation, soil fertility, climate resilience, and the provision of natural goods, directly affecting food security, livelihoods, and economic productivity. Ultimately, these impacts increase vulnerability to poverty, famine, and environmental disasters, undermining sustainable development and human well-being. Conserving wildlife and ecosystems is therefore not only an environmental priority but also a fundamental development and resilience imperative for Kenya.

In response, the Government of Kenya has invested in a range of conservation measures, including the wildlife research, monitoring and training, protection and management of national parks and reserves, forest reserves, and the expansion of wildlife conservancies, alongside strengthened legal and policy frameworks and commitments under key Multilateral Environmental Agreements. Effective implementation of these measures requires reliable, comparable, and timely scientific information. The National Ecological Monitoring Framework, supported by standardized, science-based assessment and monitoring protocols, provides a harmonized approach to tracking wildlife status, trends, and drivers of change. Its implementation will strengthen evidence-based decision-making, enhance conservation outcomes, and support sustainable development through informed investment in Kenya's natural capital.

2.0 Purpose and Objectives

The purpose of this protocol is to provide standardized guidelines and methodologies for ecological assessment and long-term monitoring of wildlife resources in Kenya. The following are the key objectives:

1. To provide an ecological assessment and monitoring tool in Wildlife Conservation areas
2. To standardize data collection protocols for all the conservation areas
3. To improve data access and sharing through harmonized storage and reporting systems
4. To provide for an early warning mechanism for adverse changes in conservation areas.
5. Support adaptive management, policy formulation, reporting obligations and decision-making.

3.0 Policy and Legal Framework

This protocol is aligned with:

3.1 The Constitution of Kenya (2010)

Article 42 on the right to a clean and healthy Environment guarantees every person the right to a clean and healthy environment, including the right to have the environment protected for the benefit of present and future generations. This right implicitly requires continuous ecological monitoring and provision of environmental information to assess environmental quality, detect degradation, and guide corrective action. Without systematic monitoring and data, this constitutional right cannot be realized or enforced.

Article 69 on the obligations of the State on Environment and Natural Resources provides the strongest constitutional mandate for ecological monitoring and information provision. It obligates the State to; ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources (Art. 69(1)(a)); work to achieve and maintain a tree cover of at least 10% of the land area of Kenya (Art. 69(1)(b)); protect genetic resources and biological diversity (Art. 69(1)(c)); establish systems of environmental impact assessment, environmental audit and monitoring of the environment (Art. 69(1)(f)); eliminate processes and activities that are likely to endanger the environment (Art. 69(1)(g)); utilize the environment and natural resources for the benefit of the people of Kenya (Art. 69(1)(h)). Importantly, Article 69(2) places a duty on every person to cooperate with State organs in protecting and conserving the environment, reinforcing the need for accessible and credible ecological information.

3.2 Wildlife Conservation and Management Act (2013)

The Act, provides a clear statutory mandate for ecological monitoring, research, data management, and provision of information on wildlife and related natural resources. While the Act does not use the phrase “ecological monitoring” verbatim, its provisions collectively establish a robust legal framework for scientific monitoring, assessment, reporting, and information sharing to support conservation and sustainable use. Thus, the act provides a strong statutory foundation for ecological monitoring and information provision by; mandating scientific research and monitoring through WRTI; requiring data-driven planning and management of wildlife resources; supporting national wildlife censuses and standardized monitoring systems; and ensuring generation, management, and dissemination of wildlife information for policy, management, and public accountability. In effect, the Act operationalizes the environmental principles of the Constitution by making ecological monitoring and provision of natural resource information a legal requirement for effective wildlife conservation and sustainable development in Kenya.

3.3 Environmental Management and Coordination Act (EMCA)

Under the Environmental Management and Co-ordination Act (EMCA), Cap. 387 of Kenya, ecological monitoring and the provision of information on natural resources are addressed through several key legal provisions and institutional functions. The Act doesn’t have a single section titled “Ecological Monitoring and Information Provision,” but these duties are embedded across its general functions, duties of the National Environment Management Authority (NEMA), and specific monitoring provisions. Section 69 of EMCA gives NEMA the legal duty to monitor the environment. In consultation with relevant lead agencies, NEMA must monitor all environmental phenomena to assess changes and their impacts. It must also monitor industries, projects, or activities to determine their immediate and long-term effects on the environment. This monitoring includes ecological aspects such as changes in ecosystems, natural resource conditions, pollution levels, and other environmental impacts. Environmental monitoring under EMCA is defined as “the continuous or periodic determination of actual and potential effects of any activity or phenomenon on the environment.” Every lead agency (government ministries or departments responsible for natural resources like water, forests, wildlife, etc.) is required to establish an environmental unit to help implement EMCA’s provisions, including monitoring. Environmental inspectors appointed under the Act have powers to enter land and premises to monitor environmental effects of activities, collect data, and ensure compliance.

Thus, NEMA must monitor environmental and ecological phenomena and the impacts of activities and the lead agencies and inspectors must assist with monitoring duties. It also collects, analyses, and disseminates environmental data, reports publicly on the state of the environment, including natural resources and the public has a legal right to access environmental information.

3.4 National Wildlife Conservation Strategy, 2030

The Strategy is structured around four core pillars, one of which is “Evidence-Based Decision Making.” This pillar explicitly recognizes the importance of data, information, monitoring and research to support effective wildlife conservation and natural resource management. It highlights the need for research, knowledge generation, decision support tools, and information sharing as essential for adaptive management and integrated planning. It also calls for strengthening systems that support data quality, sharing, and access so that conservation decisions are grounded in sound scientific evidence. Thus, it prioritizes collecting, analyzing, managing and using data about wildlife populations, habitats and related natural resources to influence policy, planning, and on-the-ground conservation actions

3.5 National Biodiversity Strategy and Action Plan (NBSAP 2019-2030)

The NBSAP for Kenya sets up a structured monitoring system to track how biodiversity actions are implemented and whether targets are being met. It prioritizes information systems — especially through the Clearing-House Mechanism — to collect, share and provide access to biodiversity and natural resource data for planning, policy, and reporting. It also promotes knowledge generation and dissemination so that stakeholders at all levels are informed and can use evidence in decision-making.

3.6 Kenya National Wildlife Census Guidelines

The guidelines define “Ecological Monitoring” as repeated surveys to track wildlife and ecological trends. It provides for mandatory use of standardized scientific methods for quality and comparability which is integral to long-term wildlife monitoring programs across ecosystems. In addition, the Census data must be analyzed, report written following scientific standards, and results shared widely with government and stakeholders. The results are incorporated into national wildlife databases for use in planning, management and policy. The guidelines also support statutory wildlife resources monitoring reports for Parliament and the public.

3.7 Relevant international conventions (CBD, CITES, CMS)

These conventions set broad obligations for Parties (countries) to collect, monitor and share data and information relevant to wildlife and biodiversity.

Under the CBD, Parties are required to identify and monitor biodiversity components to track species status, ecosystem trends, threats, and human impacts. It also establishes a clearing-house mechanism (CHM) to help countries share biodiversity information and data globally.

While CITES does not explicitly mandate broad ecological monitoring programs, its reliance on scientific advice and non-detriment findings means species status tracking is integral to compliance and to ensuring sustainable trade.

While the convention on migratory species (CMS) focuses on conserving and restoring migratory species, the implementation framework also includes requirements related to monitoring and information. CMS encourages cooperative research and data collection on migratory species trends and threats as part of agreements developed under the Convention. Periodic review of conservation status and collaborative assessments are explicitly required in action plans and MoUs while information exchange is explicitly required and the Secretariat facilitates dissemination of data relevant to CMS objectives.

4.0 Scope of the Protocol (temporal, spatial and thematic)

Ecological systems are inherently dynamic, with changes in populations, species composition, communities and ecosystems occurring as a result of natural processes such as climate variability, disease outbreaks and ecological succession. In addition, anthropogenic pressures—including habitat conversion, pollution, overexploitation of resources, invasive alien species and climate change—have increasingly become major drivers of ecological change. Both natural and human-induced processes may result in population declines, local extirpations or even species extinction. Ideally, comprehensive monitoring would capture all these dynamics and facilitate a full understanding of their underlying causes. However, given practical constraints such as limited financial, technical and human resources, ecological monitoring must be selective and strategically focused on priority elements that provide the greatest conservation and management value.

For the purposes of this manual, the selection of ecological elements for monitoring has been guided by past datasets, policy requirements and the internationally agreed biodiversity frameworks, particularly the Aichi Biodiversity Targets under the Convention on Biological Diversity (CBD) and the Kunming-Montreal global biodiversity framework which calls for ecosystem restoration monitoring and reporting in relation to target 2. Emphasis has been placed on targets that are directly relevant to wildlife conservation and ecosystem integrity, including;

1. Goal B targets addressing habitat loss, sustainable use of fish and invertebrates, pollution, invasive alien species and the impacts of climate change on vulnerable ecosystems and species;
2. Goal C targets focusing on the conservation of marine ecosystems and threatened species;
3. Goal D target on access to genetic resources and equitable sharing of benefits;
4. Goal E target on national biodiversity planning and reporting; and

5. Target 19, which emphasizes the generation, sharing and application of knowledge on biodiversity status and trends.

In addition, relevant objectives and work programmes under other Multilateral Environmental Agreements—particularly Ramsar, CITES and CMS—have informed the prioritization and design of monitoring approaches presented in this manual.

Based on these international and national commitments, the manual applies clear selection criteria for ecological elements to be monitored. Priority is given to species that serve as;

1. Indicators of broader changes within communities or ecosystems;
2. Species that are threatened, endangered or vulnerable;
3. Migratory species that require large home ranges, migratory corridors connecting key wildlife habitats and dispersal areas
4. Ecological keystone species that play a disproportionate role in maintaining ecosystem structure and function;
5. Flagship species that attract public and political support for conservation; and
6. Ecologically sensitive habitats that are particularly vulnerable to degradation or irreversible change.

These criteria ensure that monitoring efforts generate data that are both scientifically robust and directly relevant to conservation decision-making.

Within this framework, the manual covers a representative selection of species across all five major animal taxonomic classes found in Kenya—amphibians, birds, fish, mammals and reptiles. For plant biodiversity, the scope includes terrestrial vascular plants as well as marine flora, with specific attention to mangroves and seaweeds due to their ecological and socio-economic importance. Beyond species-level monitoring, the manual also addresses additional ecological elements critical to ecosystem health and resilience, including pollution, invasive species, animal health, development activities, habitat condition (water, soil and forests), and socio-economic dimensions such as tourism, bioprospecting and community perspectives in and around conservation areas.

Spatially, the manual is scalable but places primary emphasis on wildlife conservation areas in Kenya. These include national parks, national reserves, forest reserves, wildlife sanctuaries and conservancies across major ecosystem types: savannahs and arid and semi-arid lands (ASALs), forest and montane ecosystems, inland waters and wetlands, as well as coastal and marine ecosystems. This spatial focus reflects both conservation priorities and the need for standardized monitoring within areas of high biodiversity value and management intervention.

Temporally, the manual aligns with existing national monitoring cycles and survey programmes targeting key wildlife taxa including large herbivores, carnivores, small mammals, birds, reptiles,

amphibians and selected invertebrates. The National wildlife censuses are typically conducted every three years and are synchronized with ecological seasons that vary across ecosystems. These censuses largely rely on total and sample aerial counts targeting large and medium-sized herbivores. Complementary surveys, such as those for large and medium-sized carnivores using Spatially Explicit Capture–Recapture Models (SECRM), and primate censuses using ground-based methods, are more resource-intensive and are conducted opportunistically based on funding and technical capacity. Consequently, the manual emphasizes the application of standardized methods within defined periods of the year to ensure data comparability across sites, seasons and census cycles.

Given the breadth of thematic coverage and the level of technical expertise required, effective implementation of this manual necessitates strong collaboration and partnerships. Close coordination with relevant government institutions—such as NEMA, DRSRS, NMK, KFS, KEFRI, KEMFRI, the Fisheries Department, the Meteorological Department and the Water Resources Authority (WRA) as well as regional resource centers such as the Regional Centre for Mapping and Resource development (RCMRD), Intergovernmental Authority on Development (IGAD) climate Prediction and Applications Centre (ICPAC), wildlife conservation NGOs, universities, students and researchers, is essential. Such collaboration enables data sharing, comparison and integration, thereby optimizing resource use and minimizing duplication of effort. With multiple institutions involved in ecological monitoring, harmonization of methodologies, data standards and reporting formats is paramount to ensure consistency, reliability and national-level usability of the information generated.

5.0 Institutional Arrangements and Roles

- **National coordination & policy level**

The State Department for Wildlife in the Ministry of Tourism & Wildlife will be the National coordinator & policy custodian. The department will hold overall political/strategic responsibility for the national ecological monitoring framework, approve policy and national standards, and represent Kenya in multilateral fora.

- **Lead agencies**

Wildlife Research and Training Institute (WRTI) will be the lead implementing agency for wildlife research and monitoring. The Institute will operationalize wildlife monitoring at landscape/site scale in national parks, reserves and conservancies by designing site specific protocols, deploy field research teams, conducting regular censuses and routine-monitoring. The Institute will also be the National wildlife scientific authority and repository. In collaboration with National Museums of Kenya (NMK), it will provide taxonomic expertise, specimen reference collections, host biodiversity databases, contribute to indicator selection and QA/QC of biological data, and

support scientific analyses and national reporting to CBD/CITES. In collaboration with the Universities and Research Institutions, WRTI will build capacities in reviewing the development of wildlife research methods by co-designing and testing monitoring protocols (species-specific methods), running targeted research, providing statistical analyses, and training of field personnel and data analysts. KWS will deploy security teams for patrol based-monitoring, enforce wildlife laws, and collect law-enforcement / threat data. At ecosystem level, both WRTI and KWS will host the wildlife monitoring secretariat (or act as technical lead) to compile and quality-assured field data for national reporting.

- **National Environment Management Authority (NEMA)**

Provide cross-sector environmental monitoring standards, integrate wildlife monitoring with environmental quality/impact monitoring, and coordinate participatory/community monitoring guidelines where relevant. It will also ensure links between ecological monitoring and EIA/permit processes.

- **Meteorological & Remote-sensing Agencies**

The meteorological department and remote sensing agencies will provide environmental covariate data-climate, rainfall, and satellite/remote sensing data to link ecological trends with drivers (e.g., drought, land-cover change). In addition, automatic rain gauges and satellite receivers that are already installed in remote conservation areas will be used to generate the required data for the sites. For those sites where such facilities do not exist, resources will be mobilized to secure the equipment.

- **Ecosystem, County & site-level implementation**

The managers of different categories of wildlife conservation areas – National Parks and sanctuaries -KWS, National Reserves-County Governments, Conservancies-land owners and Forest reserves-KFS will implement the protocol at the local level in collaboration with WRTI regional offices. In addition, the County governments will integrate monitoring results into county planning, and coordinate with WRTI and communities on landscape monitoring. WRTI field centers and KWS field team will work closely with Community Wildlife Associations to promote Community-based monitoring & local stewardship. In addition, they will run participatory monitoring (e.g., sightings, human–wildlife conflict, community counts), provide local intelligence for ranger operations, and co-manage grazing/land-use records. The teams will keep daily/seasonal records (transects, camera traps, spoor, mortalities, earth ranger data, species tracking data), as they implement adaptive management actions, and feed data to the national data system.

- **Data management, reporting & knowledge products**

The National wildlife monitoring data Centre will be hosted by WRTI — Data and innovation hub & reporting engine. The institute will maintain the National databases (standardized formats), perform QA/QC, produce national indicators and annual reports (e.g., national wildlife census results), and service data requests for national/international reporting (CBD, CITES). The Institute will also implement shared standards, metadata, and open-data/access rules consistent with national policy on data access and sharing protocols.

6.0 Ecological Assessment Framework

- **Indicators**

The Ecological Assessment Framework (EAF) will provide a structured approach for evaluating the status, trends, and integrity of wildlife populations and their habitats using a set of scientifically defined indicators. These indicators collectively inform conservation planning, management interventions, and policy decisions by linking biological responses to ecological pressures and management actions;

a) Species abundance and density indicator

These are core indicators of ecosystem status, reflecting the number of individuals of a species within a defined area. Changes in abundance and density provide direct signals of population health, habitat suitability, and the impacts of pressures such as resource availability, exploitation, or disturbance. Regular assessment of these indicators enables comparison across sites and time, supporting early detection of population declines or recoveries.

b) Population trends and demographics indicator

These indicators examine changes in population size over time and the structure of populations in terms of age, sex, and reproductive status. These indicators provide insights into long-term viability, recruitment rates, survival, and population resilience. Understanding demographic patterns helps identify underlying drivers of change, such as skewed sex ratios, low juvenile survival, or aging populations, which may not be apparent from abundance data alone.

c) Species distribution and range indicators

These assess the spatial occurrence of species and changes in their geographic extent. Shifts in distribution may signal habitat loss, climate variability, human pressures, or ecological restoration. Monitoring range expansion, contraction, or fragmentation is critical for identifying emerging conservation priorities, connectivity needs, and potential human–wildlife conflict zones.

d) Habitat extent, quality, and fragmentation indicators

These indicators evaluate the availability and condition of ecosystems that support wildlife populations. Habitat extent measures the area of suitable habitat, while quality reflects ecological integrity, such as vegetation structure, productivity, and disturbance levels. Fragmentation indicators assess habitat

connectivity and landscape configuration, which influence species movement, gene flow, and ecosystem resilience.

e) Wildlife mortality and threats indicators

These indicators track direct and indirect causes of mortality, including poaching, human–wildlife conflict, disease, infrastructure development, and climate-related events. These indicators help quantify pressure levels, identify high-risk areas or species, and evaluate the effectiveness of law enforcement, mitigation, and management interventions.

f) Ecosystem functionality indicators

These assess key ecological processes such as productivity, nutrient cycling, trophic interactions, and species interactions. These indicators reflect how well ecosystems are functioning beyond individual species metrics. Changes in ecosystem functionality can reveal early signs of degradation or recovery and provide an integrated measure of ecosystem health and sustainability.

6.2 Assessment Levels

The assessment is applied across multiple spatial scales to capture ecological patterns, pressures, and responses at appropriate levels of management and decision-making. Assessments at national, landscape/ecosystem, and site-specific levels are complementary, ensuring that broad policy direction is informed by fine-scale ecological realities, while local management actions contribute to national conservation objectives.

a) National level

At the national level, ecological assessment provides an overarching picture of the status and trends of wildlife resources and ecosystems across the country. This level focuses on synthesizing standardized data from multiple landscapes and sites to assess national biodiversity status, population trends of key species, habitat extent, and emerging threats. National-level assessments support policy formulation, international reporting obligations, strategic planning, and allocation of resources. They enable comparisons over time and across regions, helping to track progress toward national conservation targets and global commitments.

b) Landscape or ecosystem level

The landscape or ecosystem level bridges national priorities and local management by focusing on ecological processes and species dynamics within ecologically connected areas such as ecosystems, conservation landscapes, or transboundary zones. Assessments at this level emphasize population connectivity, habitat integrity, ecosystem functionality, and interactions between protected areas, community lands, and other land uses. Landscape-level assessments are critical for understanding cumulative impacts, managing wide-ranging species, addressing habitat fragmentation, and guiding coordinated management actions among multiple stakeholders.

c) Site-specific level

At the site-specific level, ecological assessment concentrates on detailed, fine-scale monitoring within individual protected areas, conservancies, or management units. This level provides high-resolution information on species abundance, habitat condition, threats, and management effectiveness. Site-

specific assessments support day-to-day management decisions, adaptive management, and evaluation of interventions such as restoration, law enforcement, or conflict mitigation and data is collected continuously as required. Data generated at this level form the foundation for landscape and national assessments.

7.0 Monitoring Design and Methodology

Monitoring design and methodology are central to an effective ecological assessment framework, ensuring that data collected are scientifically robust, representative, and suitable for detecting ecological change over time. Sampling design determines how, where, and how often observations are made, directly influencing the reliability and interpretability of monitoring results.

a) Stratified random sampling

Stratified random sampling is used to improve representativeness and precision by dividing the monitoring area into distinct strata based on ecological or management attributes such as habitat type, land use, elevation, or protection status. Random samples are then selected within each stratum. This approach ensures that key ecological variations are adequately captured, reduces sampling bias, and allows for meaningful comparisons among strata. Stratified random sampling is particularly useful in heterogeneous landscapes where species distribution and habitat conditions vary significantly.

b) Systematic sampling

Systematic sampling involves collecting data at regular, predetermined spatial or temporal intervals, such as along fixed transects and permanent plots, grids, or time schedules. This design provides uniform coverage of the study area and is operationally efficient and easy to replicate. Systematic sampling is well suited for large-scale surveys and trend detection, as it facilitates consistent data collection over time. While less flexible than random designs, it provides strong spatial structure and is effective when combined with standardized protocols.

c) Long-term monitoring sites (sentinel sites)

Long-term monitoring sites (sentinel sites) are permanently or semi-permanently established locations where ecological variables are monitored repeatedly over extended periods. These sites are strategically selected to represent key ecosystems, pressure gradients, or areas of high conservation importance. Sentinel sites are critical for detecting long-term trends, understanding ecosystem responses to environmental change, and evaluating the effectiveness of management interventions. Data from these sites provide early warning signals of ecological change and serve as reference points for broader monitoring programs.

8.0 Wildlife Censuses

- Background

The National Wildlife Censuses shall adhere to the approved WRTI, 2024 “Policy guidelines for wildlife Censuses in Kenya”. The protocol applies nationally approved standard census strata and blocks and employs scientifically validated aerial and ground census methods endorsed by the Wildlife Research and Training Institute. This approach ensures consistency with national

standards, including data formats, species codes, and all requirements of the Wildlife Census Guidelines, thereby enabling integration and comparability of data at site, landscape, and national levels.

The guidelines provide standardized methods and timings with an overall objective of a timely provision of accurate data and information to guide policy and management decisions on wildlife resources in the Country. They also provide guidance in relation to wildlife monitoring to all stakeholders in the sector and ensures well planned and executed wildlife censuses. In addition, the guidelines provide certainty that changes detected by monitoring are actually occurring in nature and not simply as a result of different methodologies used by different researchers.

The scope of the guidelines includes all wildlife animal species (Vertebrates - amphibians, birds, fish, mammals & reptiles, invertebrates) and wildlife habitats (all plants - terrestrial & marine) in all areas where wildlife exists (Pas – Parks, reserves, Sanctuaries, non-Pas- Conservancies, ranches) at Ecosystem, County and Conservation site levels.

Five (5) guiding principles apply in the wildlife Census protocols; i) Wildlife is a public resource ii) Standard scientific methods & analysis shall be used iii) Approach shall be inclusive & participatory iv) There shall be Access & sharing of census data & information and v) The precautionary principle shall apply where necessary.

Before any Census is carried out, appropriate pre-census logistics and preparations must be considered- Considerations on budgetary requirements, required personnel, Scheduling- adequate lead time for planning purposes and Coordination- WRTI to coordinate major censuses covering large ecosystems that has multiple stakeholders – Director WRTI & DG KWS to appoint a Census Planning Committee while small-scale censuses to be coordinated by the leading institution after obtaining requisite research approvals, but with representation of WRTI. Different applicable designs shall also apply- Study design (Total & Sample aerial Counts, ground Counts), sampling units, sample frame, and targets, sample selection and size and potential sources of error. In addition, special attention shall be made to field methods depending on species & ecosystem, data management & analyses(data capture, verification, & editing, data security & archiving, analyses methods), reporting(report contents that follows standard scientific research formats, timelines and dissemination of findings and distribution for reports).

- **Design of a census**

Different designs will be used for different census methods (Table 1);

- **Total aerial Counts for large and Medium Mammalian species**

The census area shall be divided into blocks of about 600km^2. This is to ensure the aircraft assigned to one block completes the wildlife count therein in one day (6 hours, 3 hours in the

morning and 3 hours in the afternoon). Smaller blocks shall be developed from larger blocks that shall have been delineated based on certain physical features as rivers, mountains or any other barriers that can influence wildlife movements.

The method adopts total count methodology developed from peer reviewed methods including by Norton-Griffins (1978) and Douglas-Hamilton (1996). It is preceded by training for ground and flight crews on the methodology including data collection, species identification, carcass aging, and counting and estimation with confidence among others. The survey aircrafts are flown through predetermined transects spaced at 1 km intervals at a speed of about 180km/hr and 300-400ft above the ground where the crews count the targeted species and record human activities within 500 meters width on each side of the aircraft using Dictaphones and GPS equipment's. This method is applied in key biodiversity ecosystems as illustrated in table 1 below and determines the total counts for elephants, buffaloes and giraffes and estimates presence and abundance of other species larger than the dik dik.

- Monitoring objectives

1. To determine abundance and distribution of target wildlife species in the area of interest
2. To determine the extent and spread of human activities in the landscape
3. To detect trends and study the dynamics of wildlife populations over time.
4. To study patterns of spatial distribution of target wildlife species over time.
5. To identify and map threats and pressures to wildlife conservation in the landscape
6. To Inform process of developing strategies for effective wildlife management across the landscape
7. To identify wildlife corridors, dispersal areas and ecological sensitive habitats
8. To prove source of information for management planning

- Conservation objectives

Analysis of data collected will regularly and systematically provide the required insight for implementation of appropriate policy or management action. The numbers and distribution are useful in the development of management plans, development of species recovery plans, identification of wildlife corridors and dispersal areas, and evaluation of management approaches. Species number for example act as indicators of the prevailing status of the ecosystem. Similarly, the population status and movement patterns act as early warning of abnormal or undesirable state of selected conditions upon which mitigation measures are developed.

- Populations and areas to be monitored

Mainly savannah habitats and to a limited extent forest habitat represented in all the eight KWS conservation areas in Kenya which include legally protected areas, Conservancies and community and private areas that are important for wildlife conservation. Areas outside Kenya that comprise Cross border ecosystems e.g. Mara Serengeti, Magadi- Natron, Amboseli – West Kilimanjaro, Tsavo- Mkomazi, Mt Elgon – Uganda.

- Frequency of surveillance

Baseline frequency- once every three years. This is also dependent on availability of funds – wet and dry season once every three years.

- Observation / data types

A. Direct visual observations of:

1. **Wildlife species:** All species that can be identified from an aircraft at an altitude of 200-400 feet above ground. Normally these are 1) medium to large bodied mammals from the size of Thomson's gazelle up to elephant; 2) large bodied birds e.g. Ostrich, Kori bustards, ground hornbill and other similar sized avian species
2. **Livestock species:** cattle, sheep and goats (shoats), donkeys, camels
3. Mortalities of special interest species (elephant carcasses)
4. Species abundance (actual counts, estimated counts)
5. Water resources (water pans, dams, water holes)
6. Habitat destructive activities: (charcoal kilns, tree logging etc)
7. **Illegal activities:** poachers hideouts, encroachment
8. **Human activities:** traditional settlements, modern settlement (houses)
9. Spatial location (GPS coordinates and elevation data for each observation)

B. Survey parameters and target standards

Item	Survey parameter	Target standard
Aircraft	Wing Type	High wing a/c with wing struts.
	Aircraft capacity	Preferred 4-seater with two rear seat observers Two-seater allowed but not preferred
Flight parameters	Height above ground (AGL)	300 – 400 ft (91 – 120M)
	Ground Speed	130- 160 Kph
	Maximum Flight session time	4 hrs
Transects	Flight Transect orientation	North –South or East- West
	Transect spacing	Default = 1Km unless very open and less dense area where 2Km can be done
	Irregular transects	Allowed for hilly and difficult terrains
	Transect data attributes	1) Total transect length in Km 2) Total transit length 3) Total count time
calibrations	Method of calibration	Angular set up of streamers by use of clinometers
	Air craft orientation	1) Target the flight position for the air craft type 2) Plane should be horizontally leveled. Check for level with spirit level/ clinometers

	Observer specific calibration metrics	1) Fuselage to lower streamer Length on wing strut. 2) Fuselage to upper streamer Length on wing strut. 3) Length between streamers 4) Ground to observer upper eye mark 5) Ground to observer Lower eye mark
Streamers	Streamer types	Adjustable, rigid (fiberglass) rods attached to wing struts
	Observation strip widths Streamer regions	Outer streamer set at half transect spacing distance (i.e. 500 M for 1 Km transects; 1000M for 2KM) Inner streamer set at quarter transect spacing (i.e. 250 M for 1 Km transects; 500M for 2KM)
	Observation bands	Inner: fuselage to lower streamer Outer: between lower and inner streamer

- **Survey method**

The common methods frequently employed are (1) aerial total counts (2) Systematic reconnaissance flights and (3) Aerial point surveys

- **Sampling methods**

Total aerial count along line transects flown at 1-2 km intervals.

Temporary or permanent sample location

Permanent counting blocks

- **Method of sample location**

One-kilometer geo-referenced grid lines are generated for the entire survey area. The lines are located by use of GPS.

- **Number of samples**

Total coverage of the entire study area

- **Complete census or sample survey**

For aerial total counts, there is complete census in area of interest but for systematic reconnaissance flights and aerial point surveys, sample of target area are surveyed.

- **Modifications on aerial total counts methodology**

The earliest and most known description for the method is document in Norton Grifins 1978 with minor revision described in Douglas-Hamilton, (1996). Since 1996, technology has been evolving resulting in improvements in data handling, field methods, analysis and reporting. These additional amendments have been documented in Kenana *et al*. (2013) and Okello *et al.* (2015). The goal for these modifications is to exploit convenience of modern technology and to improve accuracy and reliability of the method. While applying these modifications,

consideration has been given not to radically change the method to the extent that it is incompatible with existing long-term data. The modifications added include:

(1) Use of streamers in total count.
(2) Use of voice recorders to capture data
(3) Capturing elevation data by Laser altimeter, GPS in combination with Digital Elevation Models
(4) Use of regular (rectangular/ square) counting blocks
(5) Adjusting size of counting blocks to be counted within a day.

The total count method is described here at every stage of the survey from planning, design, fieldwork, analysis until reporting.

- **Survey planning**

Every census requires planning. The degree of details required for consideration will vary with the size of the census. This would normally range from single institution census to more complicated cross boarder censuses e.g. WRTI-KWS-TAWIRI Amboseli; West Kilimanjaro; Magadi –Natron. (AWKMAN) census.

For purposes of explanation we may categorize census based on complexity of stake holders as follows:

Category	Description	Consideration
I	Single institution census	Though Planning is at WRTI level and is relatively straight forward, there is need to have several planning sessions **Recommend planning period: 6 months**
II	Collaborative census- one country (e.g. Laikipia Samburu)	Multi stake holder planning meetings **Recommend planning period: 12 months**
III	Cross boarder census – Overfly only (e.g. Tsavo Mkomazi – Mara Serengeti). This kind of census is mainly done by one country with a request for participation to the other country. An example is the Tsavo Nkomazi census, where the main base is usually in Tsavo	Requests for permission to overfly Tanzania Enlists Tanzanian participants Multi-stakeholder planning meeting Acquire overflight permission from the other country (No landing in the other country) **Recommend planning period: 9 months**
IV	**Synchronized cross border census** (involves two countries but each surveys its own blocks)	Survey done at the same time **Recommend planning period: 6 months**

V	**Integrated Joint Cross-border census** {e.g. Amboseli West-Kilimanjaro Magadi Natron (AWKMAN)} This is more complex census with the following characteristics; Commonly agreed census methodology- in the AWKMAN for example is a hybrid total/sample census with one joint planning team, one joint operation base and one Joint report	Multi stakeholders, inter country planning meetings Cross boarder permissions which require the following: Certificate of air worthiness, Certificate of air craft registration, Radio license, Operator's license, Certificate of release of service (CRS), Insurance, Crew licenses/ pilots license. These will allow for acquisition of permits upon payment of the following; Navigation fee, Landing fees at every landing, Some other fee, Immigration / customs issues (exit and entry points) **Recommend planning period: 18 months**

- **Determining survey area**

Key wildlife ecosystems in Kenya where aerial counts have been taking place have already been delineated. Continuous reviews of the boundaries can be undertaken based on emerging issues such as new knowledge of animal ranges generated from collared animals and current land uses. In the event that new survey areas are to be delineated, the following should be taken into consideration;

a) **Block boundaries:** Rivers should not be boarders of the blocks. While in the past rivers and other distinguishable features were used to delineate blocks, this is now not necessary as the use of GPS has become widespread. Rivers are often points of concentration and are not recommended as block boundaries
b) **Shape of blocks:** As much as possible blocks shall be rectangular or square shaped. This is to ease navigation for pilot and FSO and to allow for more time for observations. Irregularly shaped blocks have varying ending coordinates which require both the pilot and FSO to regularly consult with the map. With rectangular blocks, all the pilot needs to know is just the GPS reading at start and end of block
c) **Size of blocks:** Blocks should be small enough to be counted by a single plane in a single day. Care needs to be taken so as to avoid a situation where a block is counted in two days. This can be obtained by re-adjusting the blocks based on time taken to count it in previous exercises
d) **Observation gap regions**: Blocks should avoid Large areas of no (over 25Km^2) (wildlife or features of interest) such as heavily settled area (towns, villages and market centres) and large-scale crop farms and mountains. Based on previous census it should be possible to determine these areas. This is to enable economy of fuel and resources.
e) Notwithstanding the above point, extra efforts should be put to scan mountains areas as much as it is practically possible.

f) Blocks boundaries should not cut across areas of high wildlife density as determined by kernel densities of previous counts.

- **Survey intensity**

The spacing of transects will vary depending on historical densities, habitat/vegetation type and budget. The transect spacing intervals is normally between 1 and 2km, so that the searching strip is between 500m and 1000m on each side of the plane respectively. The optimum transect spacing is open to testing and improvement.

- **Survey preparations**

Survey preparations are undertaken a few days before the actual census. An advance team that moves to the census operation base a head of others normally does this. This process involves ensuring that all logistics resources required for the census are available and in place. These resources include planning maps, flight maps, data sheets, instruction sheets, equipment list, actual equipment and logistics. Roles and responsibilities of various participating individuals are also defined at this time.

- **Planning maps**

This map helps visualize the entire survey area and is useful organizing logistics for the census. Preferably, it should be a large (A0/A1) wall map that displays the entire survey area on a standard 1:250, 000 topographic map. It must show important planning features such as airstrips, road networks, terrain, labeled counting blocks, prominent features, and locations such as towns as well as administrative areas.

- **Flight maps**

These maps are carried by census flight crew (Pilot and FSOs) and are used to fly the counting blocks. They should be printed for each counting block early in advance on A3/A4 with copies for pilot, FSO and one backup. The flight maps must contain block name/codes and the target survey area name. Preferably the background should be a topographic map 1:50,000 showing various standard information such as terrain, area names, vegetation, prominent features and so on. The Flight maps should partially display portions of adjacent blocks so that the flight crew knows which blocks are next to them.

Flight maps should also show the gridlines with labeled coordinate in the desired coordinate system (UTM or geographic). The labels in the margin should be visible. The gridlines should correspond to the transect/flight interval/spacing. Care should be taken when using UTM to ensure that the correct zones (World Reference System - WRS) are used especially in transitional zones. A block should be within one UTM zone. If possible, flight maps could be printed in both geographic and UTM system.

- **Information sheet**

An information sheet serves two important functions: to instruct the crew, and to act as a permanent record of survey methods. It can be combined with planning map for small surveys. It should include the following information: Survey area, Survey code, Survey date, transect spacing, Target flying height, Target strip width, Target flying speed, Airplane(s), Pilot, FSO, RSOs.

- **Instruction and data sheets**

Instructions sheets outline detailed description of the roles for each crew (Flight and ground) in a census. These must be available in a soft copy and can be printed as needed.

Equipment

An equipment checklist (Table 3) is available and should be used for each census. Check that all equipment functions properly before packing and ensure that there are extras available in case of equipment failure.

Preflight Procedures

- **Refresher training**

This involves a quick review of training components on counting or estimation, species identification, carcass categorization, equipment operation, cabin procedures, familiarization, test flight and data handling. Participants of refresher training are those that passed and were selected from main training session and are now called to participate in the actual survey exercise. A minimum of two days will be needed to accomplish this task.

- **Calibration**

Although calibration has traditionally not be used in total counts, field experience shows that there is potential for double counting when total count transects/flight paths spacing are either close (1KM or less) or the flown AGL is high (above 400 ft). In this respect therefore it has become necessary to find a way to guide observers on how to limit their observations and also estimate distances from the aircraft. Calibration in total counts therefore is the process of determining observer specific measurements for setting up streamers on the struts of an aircraft. The aim is to guide the observer on the extent to make observations given the targeted AGL and transect/flight path spacing for the survey. It further provides a way of determining the area on the ground where the observations fall for advanced analyses. Additionally, by use of streamers the observers can be guided in estimating distances of observations. This helps in identifying and minimizing the potential for double counting. Typically, Streamers are mounted on either side of the aircraft wings to create two strip bands, the inner and outer. Inner band is defined as the region from the belly of the aircraft to the lower streamer. Likewise, the outer band is defined as the region between the lower and the upper streamer (within the streamers) (figure 1).

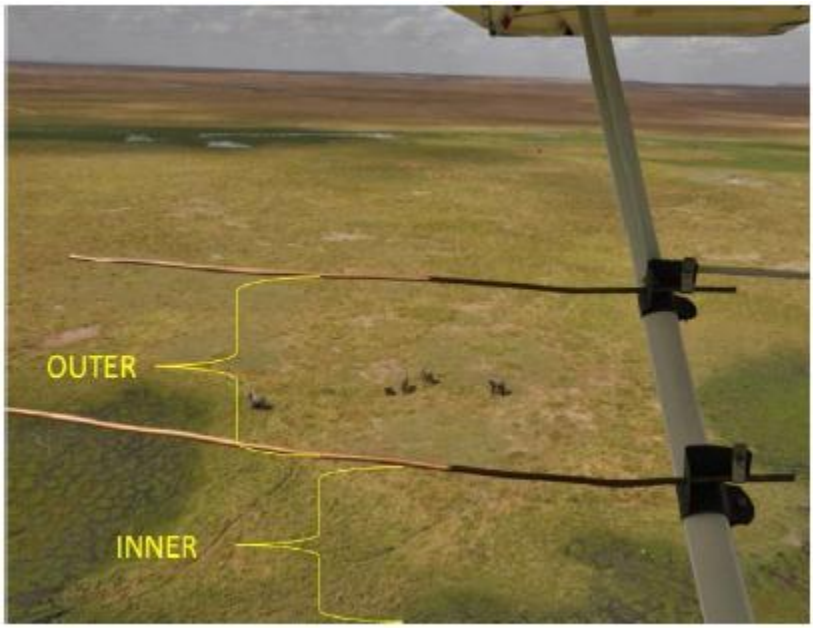


Figure 1 Position of steamers on the wings of an aircraft to help standardize distance of animals from the aircraft during aerial census animal counts. Source: Kenana et al. 2013

- **Procedure for fixing streamers and calibrating observers**

The planes should be leveled to its flight mode level. The rear seat observer gets into the plane and assumes a normal counting position. By use of clinometers, both streamers are adjusted to desired angle based on a pre-calculated angle vs strip width sheet. Observer specific measurements are generated for each observer. FSOs and pilots may optionally be calibrated for assisting the RSOs to determine whether the counted animals are within the strip width.

- **Aircraft status**

The pilot must make sure that the aircraft is serviceable, fueled and is in good flight condition.

- **Assigning count blocks**

The FSOs in collaboration with pilots and survey coordinators will assign survey blocks to planes and further mutually agree on the starting points based on safety, terrain, endurance and areas of wildlife concentration.

- **Equipment set-up**

GPS, voice records and cameras should be set to standards and agreed upon formats.

- **Setting up data lab**

This is where data is handled on arrival from the flights. It houses the GIS, transcribers, data clerks, data quality control and equipment control teams. It requires sufficient computers linked

by a common server for data base management. **GIS Team (GPS, voice recorders, camera and computer handling,):** ensure all the equipment settings are correct:

- **GPS**

1. Ensure the GPS is set to the required Map Datum (WGS 84)
2. Ensure the GPS is in the correct time zone (UTC+3)
3. Ensure the GPS is Calibrated for altitude, compass and any other parameter
4. Ensure the GPS Track log is set up as required (normally on, auto and wrap when full)
5. Ensure the GPS is in the desired Map units (UTM or Lat long) and metrics
6. If requested, upload predesigned flight plans into GPS
7. Backup existing data on GPS to a computer and clear all waypoints and tracks

- **Voice recorders**

1. Set the dates of the voice recorders
2. Switch on the noise cut option
3. Clean any previous voice records
4. Set required voice profile

- **Camera set up**

1. Check camera accessories (SD cards, mountings, external shutter, cables)
2. Mount the camera on the aircrafts
3. Ensure camera batteries are fully charged
4. Set the dates and all required settings (focus, shutter speed etc.)
5. Clean any previous photo records
6. Synchronize the camera and GPS time

- **Computer set up**

1. Ensure all computers are in good condition
2. Ensure all computers, flash disks and external drives are free from viruses
3. Establish local area network

- **Registry and equipment issue**

1. Receive all equipment and maintain records
2. Record Serial Numbers of all the equipment
3. Uniquely Label the GPS (Plane reg), cameras (Plane reg), voice recorders (plane reg_RSOR/L)
4. Issue GPS, Voice recorders to flight crew
5. Store and Issue batteries, data sheets, pencils, erasers, clipboards, species codes, Sweets (FSO), water

6. Package the equipment into boxes as required

- **General logistics**

These include efficient functions that support the census such as: transport services, accommodation and housekeeping, finances, procurement, health & safety and human resource management. These will become necessary where the census team is large (5 aircrafts and above). In such a case and for smooth operation of the census, participants will need to be centrally placed with one operation base. All items will need to be procured in good time and any financial transactions settled as need be. Transport to and from the operation base to accommodation site (if available) should be well coordinated to avoid delays.

- **Fieldwork (on flight procedures)**

During flight time, all four crews will have different responsibilities as mentioned hereunder;

- ***Pilot's role***

1) In consultation with FSO, pre- plan each flight. Pilot should find out the crew counting adjacent block and together determine the starting points and direction of covering the blocks. He/she should ensure good and safe separation distance from other flights.
2) The pilot and FSO must also decide on their start point and programme this into GPS. The start point should be about 2 km outside the block on the first flight line, so that the pilot has some time to line up on the correct line
3) Fly the aircraft ensuring safety of everyone and adhering to census flight design. The pilot is responsible for ensuring safety and separation of aircrafts at turning points or while traversing other crews counting block while on transit.
4) Maintain a suitable safe and comfortable ground speed. The recommended speed is 130 – 160 Kph
5) Maintain census target fly height above ground: height may be adapted to prevailing conditions (visibility, vegetation type etc.) A suitable mean height is 200-400 feet
6) The pilot is also responsible for guaranteeing that he she flies a 2-3km overlap into the adjacent block on each block boundary. The first transect should be at least 1km outside the block in order to give a margin of overlap, and when turning at the end of each transect a similar overlap should be left into the next block
7) When circling is required, the pilot should be able to circle around observation of interest allowing for observers to count or take pictures to their satisfaction and be able to come back to the transect and proceed with it.

8) The pilot should participate in the counting only in so far as he can comfortably do so. In many cases, the pilot's vantage point can prove particularly useful in drawing the observer's attention to the animals coming in the plane's flight path

- ***Observer's role***
- ***FSO role***

On flight, the FSOs will have primary responsibility for navigation and data recording onto a datasheet and will specifically undertake the following:

1) Ascertain that all his/her equipment are well set up and functioning correctly.
2) In consultation with the pilot, determine the start point and direction of progress of the count.
3) On takeoff, check the time on GPS and clearly communicate the take-off time so that the RSO can echo it into their voice recorder .
4) Assist the pilot with navigation and cross check that the pilot is flying in the right block and turns and the right place
5) Alert the RSOs about commencing of counting about two Kilometers to the start of the count.
6) Communicate to the RSO the start count time so that the latter can echo back on the voice recorder.
7) Be responsible for the actual recording of data into a data sheet. He/she shall be attentive to RSOs call outs as they do the actual counting and on hearing each call, He/she shall take a GPS waypoint and shout the waypoint number so that the RSO can call back the waypoint into the voice record to associate it with the observation.
8) Record onto the data sheet the waypoint number, species, the streamer region, the aircraft side, the estimate and any photograph taken for each observation as the RSO are counting and calling out.
9) Be certain the pilot is flying a satisfactory overlap into the adjacent blocks
10) In consultation with the RSOs and the pilot, adjust the strip widths as necessary.
11) At the end of counting, provide the stop count time.
12) Give the landing time to the RSO on landing

- ***RSO role***

On flight, the RSOs shall primarily be responsible for spotting, identifying, counting or estimating, photographing and recording into a voice recorder all observations required in the census. He/she shall specifically undertake the following:

1) Ensure that his/her voice recorder is properly functioning and well set up. He/she should particularly ensure mastery of the play/pause buttons of the voice recorder and how to use them appropriately.
2) Observe his/her side of the aircraft, spot and identify the observation of interest.
3) Count (or estimate) as the case may be, the species that are being enumerated in the census.
4) Clearly, audibly and loudly call out the observation into the voice recorder ensuring a complete voice data record. A complete data record is one that has 1) the species (observation), 2) the Side of aircraft (Left/Right), 3) steamer region (Inner or outer), 4) estimate, and 5) waypoint number. He/she should however make every effort not to call out their data at the same time as their fellow RSO is calling out his/hers. He/she should try to commit their information to memory and call it out to the FSO at the earliest possible opportunity or when requested by the FSO
5) On encountering a large heard of elephants (or any species of species interest that require circling), notify the Pilot and FSO to circle so that they can count well and take photograph
6) Take photograph of the observations of interest as per the requirements of photography for the census

- ***What to count***

All animal species, which can be spotted and recognized from the air, including livestock, are counted. All carcasses spotted should be identified and recorded. Elephant carcasses are categorized into classes:

1) Fresh (less than 3 weeks old): where there is still flesh beneath the skin giving the body a rounded appearance and a pool of body fluids is still moist on the ground. Vultures may be present
2) Recent (more than 3 weeks old but less than 1 year old): the skin and the bones are mostly in place, an open rot patch is present around the body from the decomposition fluid which have killed the surrounding vegetation
3) Old carcass (more than one year old): where only a skeleton is present with white bones visible, vegetation will have started to re-grow and the rot patch has disappeared. Skin may be still present
4) Very old carcass (up to ten year old): where the bones are grey and cracked and widely scattered so the carcass does not stand out as a distinct entity. Difficult to spot from the air.

Other observations to be counted include:

5) Important wildlife resources e.g. watering points, salt licks etc.

6) Illegal activities e.g. poachers, poacher camps, mining, livestock bomas, settlements
7) Human activities e.g. schools, settlements, bomas, farms.

Post Flight procedures

- **Pilot**:

1) Must fill-in the aircraft log book and any other data sheet for the pilot
2) Hand over his/her GPS to the FSO.
3) Check the performance of his/her flight from the data management team. Of interest will be that the blocks were well covered and transects were flown in neat straight lines. Further that that other flight parameters (ground speed, flight height) were as per the requirement of the census. If there is any problem with any of these items, a decision will be made in the consultation with the coordinators as to how the flight and data collected from it will be treated.
4) Monitor and oversight the refueling process for next session.

- **FSO**:

1) Gather all the equipment with data that include the GPS, voice recorders, camera and data sheets and hand them over to data management team.
2) He/she should also make a follow-up with the data management team to ensure the block is well covered. If the block is not well covered due to any reasons, a decision will be made in the consultation with the coordinators.
3) Must also clean all the data sheets and make sure that they are legible.
4) Be available for the data team to clarify any issues with his/her data

- **RSO**:

1) Hand over all equipment (Camera and voice recorders) to the FSO.
2) Make a follow-up with the FSO and data management team for any anomalies, if any.
3) Be available for the data team to clarify any issues with his/her data

- **Data management Crews**

The crew is composed of: GIS team, Data base team, Transcribers, Data entry clerks, Data quality controller and equipment registry.

- **GIS team (Downloads manager and GIS supervisor)**
- **Downloads manager**

1) The download manager shall receive data sheets, GPS, voice recorders and cameras from FSO
2) Download waypoints, tracks/GPX files, voice records, and photographs and assign unique naming convention. A good naming convention should be able to give descriptive information such as: Aircraft ID, Block No., session, and date.
3) Cleanup way points and tracks (make ready for use) Delete and Reset confirmation after every download
4) If requested, upload predesigned flight plan to GPS
5) Confirm GPS is ready for next session
6) Download manager hands over all the data to GIS supervisor.

- **GIS supervisor**

1) Receive all data from the download manager
2) Compiles tracks and waypoints (spatial information) into a GIS environment for immediate display to census team to assess progress of census
3) Undertakes noise clean-up of voice records
4) Distributes the voice records to the transcribers to transforms voice data to spreadsheet data (Data sheets)
5) Collect transcribed data sheets from the transcribers
6) Label and file transcribed data sheets according to planes
7) Distribute the data files to data entry clerks for input into the database

- **Data transcribing**

1) Receive cleaned voice records and transcribe them onto data sheets
2) Compare and cross check the transcribed RSOs L/R data with FSO's data sheet and note any discrepancies
3) Seek for clarification from the RSOs and FSO concerning any unclear recording

- **Photo count clerks**

1) Shall receive photos from the GIS supervisor
2) Shall use the transcribed data sheet and fill the photo count data columns to corresponding entries
3) Where pictures overlap, determine the overlapping portion of the photos and count the animals in this area only once.
4) Record the total number of animals on the photo. Pay attention to places where the estimated herd size and counted herd size differ greatly, because this indicates some problem with the numbering of photographs.

5) Where more than one set of photos exist for the same group, chose the better one to count. If two sets of photos give different totals, the higher total is usually assumed the more accurate.
6) All photographs should be counted a second time by a different party

- **Data entry clerks**

1) The data entry clerks shall receive the dully-filled transcribed data sheet from the GIS supervisor and key them in to the data base.

- **Data base administrator**

1. Shall manage the data base server
2. Backstop data entry issues
3. Link database and spatial GIS data
4. Run queries and produce any required reports

- **Standards and data quality controller**

This should be someone thoroughly knowledgeable in aerial census operations and data management matters ideally the principle investigator. He/she is aware of the design, objectives and required analyses from the census data. His/her main role is oversight ensuring due diligence is exercised at every point of data collection and handling and that desired standards for the census are achieved. More specifically, he/she shall be undertaking the following:

1) Be the chief refresher trainer and provide technical instructions to the team.
2) Review dry run and refresher training data to confirm that required standards for the census are met and the team can proceed with the actual census.
3) Ensure that all the data handling and processing steps are undertaken with the highest diligence
4) Undertake checks and test after every download and note any deviations from the required set up and standards
5) Undertake validation of the data sets (check data integrity, completeness, processing and handling)
6) Undertake daily analyses and review of crucial census parameters (observer performance and consistency, flight parameters performance (speed, elevations transect sinuosity and so on).
7) Make decisions based on the quality of data captured, of whether to use or reject the data and call for a recount of the particular data
8) Trouble shoot data management issues as needed

- **Census Team leader**

1) Coordinate with flight and ground crew to ascertain everything is going on smoothly and any issues addressed within the flight sessions
2) Be the master of ceremony in all meetings or briefs.
3) Establish de-briefs agendas after all flight sessions of the day
4) Asses progress and identify gaps
5) Address challenges encountered
6) Receive suggestions from flight and ground crews
7) Overseeing plans for the next day's work plan

- **Data validation and verification**

Data validation and verification includes various processes such as:

1) Trapping data entry errors for example entering wrong species code or name (use of RDBMS rather than spreadsheets minimized these type of errors)
2) Trapping logical errors: for example recording 20 lesser Kudus instead of 2 (for this use animal knowledge of animal behavior to scrutinize suspicious entries)
3) Identifying and removing double counts. See explanation in rules for standardizing
4) Verification of observed numbers using photos.
5) Processing the data so that it is in the required format for analysis,
6) Ensuring all required meta- data are provided, and the dataset is complete not having any fields missing.
7) Verifying that what was captured in the field is what is appearing in the database or spreadsheets. This often requires consulting with data sheets, voice records and memory of the observers.

- **Timing of surveillance / observations**

Recommended times for aerial surveys are early to mid-morning and late afternoons when most animals are active and have not hidden under trees due to the heat of the day. It is recommended that the season of survey be maintained over time for maintaining seasonal bias. If possible, it is recommended to do the survey in the wet and dry season in a particular year.

- **Potential causes of bias and rules for standardization**
- **Sources of bias**

1) Inter-observer variability: to minimize this is to maintain same crew for multiple surveys as much as possible
2) Estimation of abundance: training will minimize this

3) Distance estimation: use of streamers will help in this
4) Aircraft type: 4-seaters recommended over 2-seaters for high wildlife density area
5) Coverage; may not be complete because of difficult terrain and blind spot (aircraft under belly especially for small mammals where circling is normally not done).
6) Habitat cover; to explore newer solutions for correction of habit biases (forest and closed woodlands where visibility is poor)

- **Rules of standardization**
- ***Identifying and removing double counts*** (within and among blocks).

When deciding if a double-count has occurred, consider the following:

1) Same or different planes: (All else being constant, and assuming that the crew of one plane would recognize a herd it had seen before, and be aware of where it had flown before, two groups recorded by the same plane on the same day are considered to represent two different groups.)
2) Time between observations: (Allowing for movement of the herd) observations recorded close to each other with different numbers are considered to be separate
3) Similarity in number of animals (slight differences might be expected between photographs but not large ones. Go back and examine original photos to see if quality of photo might account for difference in number of animals counted. In particular, distant photos tend to give lower counts than close ones.)
4) Proximity of the two observations (could animals move that far in that amount of time?). Using GIS script, select all observations that are within 500M of each other, then check if same species, then check if same numbers. if both are true then scrutinize them further for possibility of double count. Consult with observer as need be.
5) Order of counting groups: By plotting group numbers it is possible to see the path of the aircraft even when a recording GPS was not used. You might assume that the crew would not count the same group twice one right after the other, but that it might double-count it if it had flown off and done several other groups in the meantime.
6) Habitat type of the observation: Use the photos to see if two photos taken close together in space and time are taken in the same place.
7) Keep a record on paper of all the decisions you had to make under in determining double count s, and your justification for each decision. Often a decision is very difficult and you will have to decide how to handle questionable cases. Whatever it is, this decision should be explicitly stated in the database and subsequent report.
8) When deleting a group due to double counting, don't just delete it. Instead, create a new column in the attribute table called "double counted" and move data points to that layer. It can be made invisible but still retained for future reference this way.

Keep a record of all the changes you make and file it for future reference.

- **Height above ground level (AGL)**

This is best obtained using laser/radar altimeter readings. Approximate height above ground can be determined using GPS elevation in combination with Digital elevation model for the target area. In which ever form once obtained, create a Frequency histogram (3 meters intervals) for entire flight; Calculate mean, standard deviation. Compare mean Height AGL against target Target height +/- 10% SE allowable; check with pilot when outside bounds, change pilot if consistently >10% variation. Re-fly transects where necessary.

- **Ground Speed**

Frequency histogram (20 Kph intervals); Calculate mean, standard deviation. Compare mean Ground Speed against target Ground speed should be no less than 130 kph and NOT exceeding 180 kph for entire transects or for more than 30 seconds in a given transect. Discuss with pilot if ground speed significantly different on reciprocal headings; re-fly transects if necessary

- **Observer Consistency**

For each observer, calculate the total the number of groups recorded and the total animals counted (corrected by photo-counts); perform a chi-square test for statistically significant differences between left and right observer. 45% - 55% difference between pairs is OK; 40% - 60% worth looking into; <40% and >60% indicates a significant problem and requires some investigation. It is expected that for a large number of observations, both observers should see statistically similar observations.

- **Monitoring requirements**
- **Personnel responsible**

• **Flight Crews** 1. The Pilot 2. Front seat observer (FSO) 3. Rear seat observer (RSOs) • **Coordinators** 1. Principal investigator 2. Field Supervisor 3. Logistics & Coordinating officer 4. Wildlife managers (e.g. KWS warden)	• **Data handling crew** 1. Data entry clerks 2. Transcribing clerks 3. Photo count scientist 4. Database Manager 5. GIS supervisor 6. Quality control supervisor • **Ground Logistic Support** 1. Housekeeping 2. Drivers 3. Guards/security team 4. Flight engineers, 5. Technician 6. Attendants/refuellers

- **Full scale training**

Training for a total count should be taken seriously since it has direct implication on quality of data. It is recommended that an annual training be done to potential participants in the census. This will be the entry point especially for new people. This training should be able to identify suitable persons to undertake the various functions in a census. full-scale training takes a minimum of five full days and should include both theory and practical aspects. The content for this training includes:

1. **Species identification**

RSO and FSO should be able to identify all species of interest from the air and be able to distinguish the lookalikes e.g. Gravy's Zebra Vs Domestic donkey and Burchell's zebra, Eland vs Oryx etc; ROS should be able to make observation/how to spot animals and associations (animal behavior)

2. **Counting and estimation**

Where counting is required as in the case of species of special concern (elephants, Grevys Zebra etc) , RSO must be able to accurately count and estimate large herds of other species.

3. **Elephant carcass ageing**

Observers should be able to identify and categorize elephant carcasses according to MIKE standards

4. **Census equipment operations**

FSO must be able to give and record waypoints; GIS personnel should be able to set up, calibrate , download all types of GPSs; RSO must be able to effectively capture data into voice recorder; Ground crew and FSO shuld be able to set up and use altimeters; ground crew should be able to use inclinometer to calibrate streamers for planes; Ground crew should be able to setup the camera and mount of aircraft; RSO should be able to use the camera to take photos; Data handling crew should be able to use softwares used for various functions in census (GIS, RDBMS, spreadsheets, Networking etc) .

5. **Cabin procedures**

(communication with in the cabin, complete data capture sequence ,on flight crew coordination); RSO must be able to report a complete data into voice recorder i.e. species names, number, region/side and GPS position altogether for each observation; RSOs must be able to capture all header information i.e. the survey area, date, crew composition, aircraft details, session, bock/transect number, takeoff time, start count time, stop count time and landing time

6. Navigation using GPS and flight maps

Pilots and FSO must be able to read maps and navigate using GPS

7. **Census flying**

Pilots should be able to nicely circle observation of interest, maintaining straight transects, maintaining target height, safety issues

8. **Calibrations theory and practice**

Ground crew should be able to calibrate the observers and set up streamers well

9. **Endurance and concentration**

Flight crew should be able to maintain concentration even in long flights

10. **Visual acuity tests**

This is not a training but a prerequisite for all observers especially RSO. The Flight crews must have good eye sight

11. **Data handling and processing**

- Data entry crews must know how to enter data correctly; zero error
- Data handler must know to
- Data crew must be able to calibrate and set up all GPS, voice recorders and cameras
- Data crew should be able to download all types of GPS and voice recorders used
- Data crews should be able to adopt a systematic file naming protocol to match various data sets (way points, tracks, voice records and photographs)
- Data crews must be able to digitally clean voice records
- Data crews must be able to quickly validate and check data entry errors
- Data crews should be able to verify data collected from photos
- Data crews should be able to do photo counts and match them to the observations

- **Equipment required**

Aircrafts, vehicles, GPS and accessories, clip board, pencils, pens, erasers, computers, cameras, datasheets, toposheets, first aid kits, sweets, water, Streamers, voice recorders, clinometers

Table 3. Equipment checklist

• **Equipment on air craft**	• **Pilot Folder**
Aircraft intercom headphones	Flight (topographic) map
Laser/ radar altimeter and accessories (cable, Tab)	Planning (size A4) map
Streamer rods	Pilot Instruction Sheet
Wing strut streamer brackets	FSO Folder
Tool box	FSO Instruction Sheet
Altimeter bracket	Census Data Sheets
Drum opener	Flight map
Fuel pump	Planning (size A4) map
Oil and oil filter	Pencils
Avagas	Erasers
Sick bags	Pencil Sharpeners
Window cleaner	Clipboards

Sunscreen reflector	RSO - Folder
Clinometer	RSO Instruction Sheet
Clinomter Calibration Rod	RSO Species Code List
Calibration angle table – Distance angle table	
Duck tapes	
Old tyre tubes	• **Data management**
• **On Flight data capture equipment**	
GPS	Printers both A3 (color) and A4 installed with
GPS Batteries	Computers (both desktop and
GPS downloading cables	Headphones
Voice Recorders	Network accessories (Hub, LAN
Voice recorder batteries	Power source, extension cables
Camera	Software (GIS, audio, GPS downloading, data base, antivirus,
Air craft Camera mounting	Flash disks, external hard drives
Memory cards for camera	Stationary (Files, Printing papers, paper punch, etc)
Camera chargers or batteries	LCD projector
Shutter release cables	Supplies
Camera download cables	Store room
• **Logistics**	Masking tape
First Aid Kit	Tape measure
Drinking Water	
Sweets	

- **Data recording and storage**

a. GPS settings

The following are the things to observer: All GPSes must be registered and the following checked to be ok: (Map datum and units). GPSes must be uniquely labeled. The goal is to tie every observation to a particular GPS. It is a good practice to take a waypoint of a common reference point and a particular elevation for all GPS. This will be used to offset with the DEM.

b. GPS downloads

After every flight tracks and waypoint should be downloaded and appropriately labeled.

(c) Data entry and transcribing

Data from datasheet are entered into a spread sheet by the data entry crew. Data from voice recorders are listened to, then a datasheet is filled and this is then entered into the spread sheet. At this point the ground crew verifies with data sheets and voice records whether all information are entered correctly. If not the team consults with the observers.

d) Noise removal from voice records.

Modern voice recorders are digital enable capture of digital voice records. Often there is a lot of background noise from the air craft which can make the process of transcribing data hazardous. Efforts should be taken to remove or reduce background noise. There are a number of free software available to do this.

(d) Data validation

(e) Merging attribute and spatial data

Once the spreadsheet data is processed to a satisfactory level, it should be joined with the spatial information. After this process data clean up commences and double counts be investigated and eliminated.

- **Data analysis**

Basic analyses is done immediately upon completion of the census and more advanced analyses can be done as per specific information needs. Basic analyses may include:

1) Generation of tables of results as per reporting needs (entire area, historical blocks, ecological zones, administrative areas)
2) Generation of shape files and theme for target species
3) Creation of distribution maps for target species
4) Group size frequency analysis
5) Trends analyses
6) Abundance calculations
7) Density estimates: (simple densities No/Area), Kernel densities
8) Feature overlays

Advanced analyses include;

1) Conduct array spatial analyses as per objectives (Density analysis, hot/cold spot analysis, near feature, clustering, spatial patterns analyses)
2) spatial statistics relationships e.g. specific species vs biotic and abiotic factors e.g. water, habitat)
3) Spatial modeling
4) Trends analyses for future projections
5) Bias analysis – there is need to find a way to address sources of error in total count which result from;
6) Observer bias (under/over count); determine observer and survey specific correction factors from photo counts to minimize biases.

7) Coverage; may not be complete because of difficult terrain and blind spot (aircraft under belly especially for small mammals that we normally do not circle to verify their numbers).
8) Habitat cover; to explore newer solutions for correction of habit biases (forest and closed woodlands where visibility is poor)

- **Reporting procedures**

a) Technical reports and Publications
b) Funding institution reports
c) Area management report
d) Library

- **Indicators**

i. Trends in numbers and distribution of wildlife
ii. Trends in numbers and distribution of wildlife mortality
iii. Trends in numbers and distribution of Livestock
iv. Trends and distribution in wildlife area encroachment
v. Status and distribution of wildlife resources
vi. Trends in land use changes
vii. Trends and distribution of illegal activities
viii. Trends and distribution of invasive species

- **Institutional collaborations**

(A) Government institutions e.g.

- Tanzania Wildlife Research institute (TAWIRI)
- Wildlife Division of Tanzania (WD)
- Tanzania National Parks (TANAPA)
- Department of Remote Sensing and Resource Surveys (DRSRS)

(B) Non-governmental organizations e.g.

- African wildlife foundation (AWF)
- IFAW
- Save the Elephant
- Tsavo Elephant Trust

(C) Private individuals e.g.

- Peter Zanneti

(D) Conservancies and ranches

- Rukinga Ranch/ Wildlife Works
- Northern Rangelands Trust

8.2.2 Sample aerial Censuses for Large Mammalian species

The Census area shall be divided into grids measuring 5km by 5km and each aircraft shall be assigned about 100 units each day (early morning and late afternoon). Since 1970s, DRSRS has conducted such similar sample counts and therefore it is crucial that these counts are continued to allow for statistical analysis of population trends into the future.

This entails Systematic Reconnaissance Flight (SRF) methodology described by Norton- Griffins (1978). It is preceded by refresher training for ground and flight crews and calibration of aircrafts which includes flying altitude of 400 ft above the ground and counting targeted species within a strip of 300 meters on both sides of the aircraft. The method is used in the northern parts of the country including Garissa, Wajir, Mandera, parts of Marsabit and Turkana.

8.2.3 Total ground Censuses for Large Mammalian species

The study area shall be divided into blocks that can be covered in about 4 hours by vehicle. The road networks act as block boundaries. The blocks should have adequate road network to enable the observers to drive within it and using binoculars to count the wildlife therein. Where the ground census is done on foot, the roads are used as bases for starting point of transects.

8.2.4 Sample ground Censuses

The method entails walking or driving along established roads or using predetermined transects and counting wildlife species on both sides of the road/transect. It is applied in key biodiversity ecosystems to complement total and sample aerial census. In forested ecosystems, other approaches including estimation of species abundance using dung counts and camera traps, e-citizen are applied. In addition, the method is used to count species not included in aerial censuses like birds, primates and small mammals. The method is also used for small mammals like rodents, shrews, bats, amphibians, and reptiles using different tools depending on targeted species including mist nets, sweep nets, pit traps, camera traps, and Sharman traps among others. It is is also used for vegetation surveys during ground counts by applying line or strip transects for woody vegetation and quadrants for herbaceous plants and grass species.

Different methods are applied to count carnivore species. These include camera traps, individual identification using Spatially Explicit Capture Recapture (SECR) and Capture Mark Recapture Techniques (CMRT), and call backs of recorded herbivore sounds, and spoors count.

Ecological data collected on regular basis enables managers to identify wildlife trends in a park or an ecosystem. Species numbers, act as indicators of the prevailing status of the ecosystem. Population status and movement patterns of animals act as early warning of abnormal conditions of selected conditions upon which mitigation measures are developed. Under normal circumstances wildlife numbers do not change rapidly. Changes are small and gradual hence the need to carry out regular counts to detect them. For example, we need to know if the population is slowly increasing, slowly decreasing or not changing at all. Knowing this trend

in population numbers allows us to make reliable management decisions and take corrective actions when necessary & design management policies

- **Monitoring objectives**

1. Estimation of populations and abundance of species
2. Establishment of species population structure, trends and movement patterns
3. Modelling for deductions or predictions using physical parameters and other biological attributes
4. Establish threats.

- **Populations / areas to be monitored**

All large and medium sized animals (size of a dikdik and above) are counted using this protocol as long as they are visible. The type (species and sex) of animals seen, the numbers of animals seen, when the animals were seen, (e.g. the month of the year; the dry or wet season).

All protected areas, community ranches/conservancies and privately-owned ranches/ conservancies in the rangelands where wildlife is found are recommended. In areas where similar work has been going on, there is need to continue with the same methods to ensure future comparisons with past data. For example, in mountain conservation area (MCA), Laikipia and Samburu counties, Rhino sanctuaries and conservancies (Ol Jogi, Ol Pajeta, Ol Arinyiro, Mugie, Lewa, etc), dams (seven forks) and Lakes (Ol Bolossat etc) have been a priority and there are transects already in use. Sampling of these transects should continue.

In Southern Conservation Area (SCA), Nairobi National Park has a working program which has been on-going for many years. Within Kajiado county ranches and Machakos ranches, there are existing counting blocks while in Amboseli there are established road count transects.

In Tsavo Conservation Area (TCA), the Voi sector in Tsavo East National Park has a well-established road count and road kill survey activities which are implemented monthly (figure 4.1.21). This has been going on for many years. In Taita Hills Sanctuary, the recently marked counting blocks should be maintained and continued.

In the Central Rift Conservation area (CRCA), Lake Nakuru National Park and the Naivasha/Nakuru ranches have well developed transects and blocks for such monitoring.

In Meru Conservation Area (MCA), the road count system should continue. For those protected areas where such transect counts have not been established, it is hereby recommended that they should be established and implemented as per the protocol.

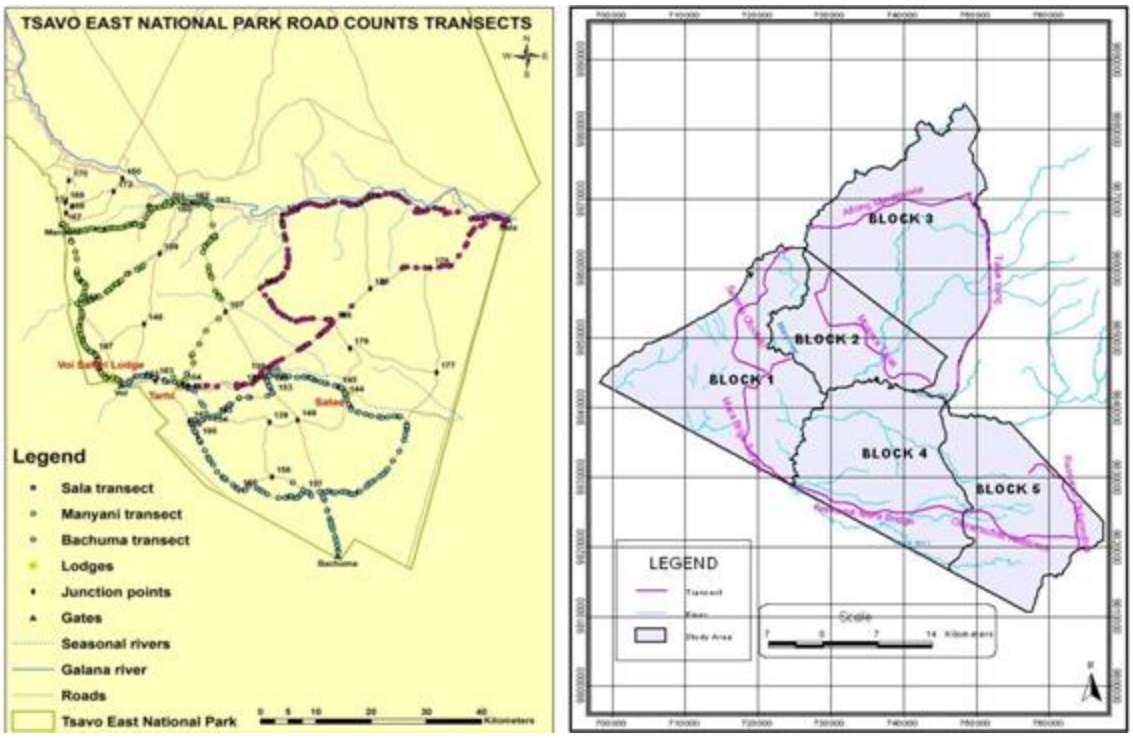


Figure 4.1.21: Examples of established transects

- **Monitoring methods**
- **Total Wildlife Block count**

Two common methods are recommended for this protocol; the Road strip counts by vehicle and walked transects by foot.

- **Delineating counting blocks**

Total ground count aims to count all the animals or specific animal species in a defined area. This is either done from a vehicle or foot.
Ground counts from vehicles are practicable in small to medium sized (such as Nairobi and lake Nakuru National Parks) areas where: -

1. the area can be traversed by vehicles,
2. where the vegetation is reasonably open (savanna grassland) and;
3. the animals are tame to vehicles

Census units are delineated into discrete counting blocks, usually bordered by well-defined features such as roads, rivers, escarpment edges, mountains or the park/reserve boundary to enable a near effective coverage and spotting of available wildlife from vehicle or foot teams. The blocks should be kept as permanent as possible for continuous comparison. The procedure should be continued in areas where it has been taking place for a very long time, but the methodology should be enhanced by recording the GPS' location and distance (by use of range finder) and direction (compass) of located animals undertaken to allow for effective analyses of

data and plot of actual dispersion. The method could also be incorporated in the MIST procedure.

Initially the total area is divided up into blocks based on habitats then transects known as sample units are identified. Ground counts from vehicles are only practical when there is good access and visibility and when the animals are reasonably tame to vehicle. Given these conditions, reliable and consistent results have been obtained.
Transect sample counts aim at estimating the number of animals in the total area within the census units from the number counted in a smaller area (the sample unit). Sample counts make two important assumptions:

1. That all the animals in the sample area or unit are seen and accurately counted
2. That animals are spread evenly throughout the whole wildlife area or census unit for which the population is being estimated

- **Planning and preparation**

Before the counts, the coordinator has to plan on:

- Who and how many people will be involved?
- How will wildlife counters get to the transects?
- What other resources will be needed?

After arriving at the counting area, everyone is briefed on what method is being used, what animals are to be counted, how the information will be recorded and what safety precautions should be taken.

- **The wildlife area and position of transects**

Each block has transects marked. Transect lengths are measured and are permanently recorded

- **Dividing the groups**

Participants are divided into groups of at least three, with the leader having a rifle.
Each group has a pen, a watch, a counting form and a clipboard. If the participants are not familiar with the area a compass is also given.

- **Allocation of transects**

Using the map, each group is shown the start and end points of the designated transect and then go to the designated transect either by vehicle or foot. The participants must agree on how they will communicate with each other before the count commences.

- **Moving off**

As the team starts moving, the recorder notes the starting time. The other two members maintain a straight line with the centre member who acts as recorder. The team maintains transect direction by using natural land marks in front of them.

- **Searching for animals and recording observations**

All members of the team search continuously for animals in an arc of 180 degrees to the left, front and right as far as they can see. On making an observation, the team stops, records what has been seen (animal species and number) and the time, before continuing to walk.

At the end of the transect, the time is recorded on the transect counting form and counting stops. Animals seen when moving between transects or on the way to the pick-up point are not recorded

- **Avoiding danger**

During the count participants may come across dangerous animals such as lions, elephants or buffaloes. If these animals are in the transect, the team members regroup and discuss ways of bypassing them, but ensuring that they are all counted. Wind direction is an important consideration. At the same time the team members observe a land mark in front of them within the transect which they use to maintain the direction once the animals have been bypassed.

- **De-briefing**

Following the count, each team hands over their data sheets to the coordinator who checks them to ensure they have been completed properly. Date, block and transect numbers, transect lengths, start and end times, species and time observed and number and names of observers are all items of information that require checking

- **Where and when are road strip counts used?**

A road strip count is the most common way of ground-based sampling. Road strip counts are usually used in smaller wildlife areas (100 - 1000 km^2) and game ranches.

- Advantage

Road strip Counts provide estimates for more species than an aerial survey because most species larger than a duiker will be seen.

- Disadvantages

using a vehicle however, include the need for a well established road system that is not biased towards certain habitats an accurate measurement of the distance of each sighting from the road and the need for vehicles make it relatively expensive.

The analyses can be quite complex too.

- **Where and when are Foot walked transects used?**

Walked transects are used mostly on small wildlife areas (100 - 500 km^2) like game ranches or where there is a strong level of community management, especially in communally owned land. The observer or observers walk along transects counting the animals seen on either side of the transect. Just like a road strip count, it is important to measure the distance of the animals from the transect and the length of the transect if an estimate of the population is to be calculated.

Walked transect counts have the advantage that the observers will probably see a greater range of species than any of the other methods and it is a relatively cheap method of estimating wildlife populations allowing a high level of community participation.

Sampling transects are then randomly picked from the sampling units. Distance sampling method as described by Buckland, et al. (1993)

Distance sampling techniques provide estimates of density which have proved to be accurate estimates of absolute density. These estimates were comparable with mark recapture measures but at greatly reduced effort and less disturbance to the animals and environment.

- **Data analysis**

The number of transects per vegetation type is proportionately allocated based on the area of each vegetation community as calculated from the vegetation and the sector map. Following the determination of species presence and distribution, two very different measures of abundance are estimated during the sampling of an animal population. The first is absolute density which is a quantitative measure of numbers per unit area. If the relevant area is known, this can be converted into an estimate of population size, or abundance. The second is relative density and refers to population densities relative to a unit other than an area, for example, per unit of habitat [skinks per upturned rock], per unit distance [possums per kilometer walked], or per unit time [birds per 5 minute count]. Relative density is an index to population size and can be used if the actual size of a population is not required. Distance software is applicable here.

- **Recording results on a transect analysis sheet**

The Co-coordinator explains how the results from the transect counting forms will be compiled and analyzed. Participants are divided into groups. Each group is asked to draw up a transect analysis table on the back of the data sheets. They do this by asking each of the original team of

three members to record the observations and total numbers of animals seen in their transect, on the transect analysis sheet for each block.

- **Summarizing results for all blocks**

The total number of observations and numbers for each species for all the transects are then added up and the totals for each block are transferred to the Area Analysis Sheet which summarizes the results for all blocks. The total number of observations and animals for the area is found by adding all the observations and numbers for the blocks.

Reporting procedures

a. Technical reports
b. Publications

- **Potential causes of bias and rules for standardization**

The main sources of bias arise from

1. failing to effectively comb the whole area,
2. failing to locate/identify all the animals and
3. Failing to count animals accurately or double counting.

Vehicle road counts are open to bias when the road networks are not randomly designed and therefore unlikely to be representative of the area. In some areas with a high level of human activities, animals tend to avoid the roads resulting in low estimate. The slow rate of coverage also makes this method impractical to use in large areas.

- **Considerations when organizing ground-based counts**

Factors which affect the distribution of animals or their likelihood of being counted will affect the accuracy of the sample: In terms of visibility of animals, the surveys are more accurate for large, dark bodied animals such as elephant, buffalo and sable, which are easily seen. The type and state of habitat is also another factor. It is more difficult to carry out sample surveys in hilly or mountainous areas. Sample surveys are normally carried out in the dry season when animals are easier to see because the trees will have lost their leaves. Animals found in large herds are not easily counted and there is need for training on animal behavior. Distribution of habitat also affects the quality of the data as wildlife is usually found where there is food, water and shelter. So the survey needs to sample all types of habitat equally. The greater the number of sample transects, the closer the estimate will be to the true number.

The Size of the wildlife area, type of habitat and resources (human and financial) at your disposal are key issues to consider before undertaking the survey. In very large areas (>1000

km^2), a sample count from an aircraft is recommended although its expensive. Areas with a strong community involvement e.g. community ranches, sample surveys may be carried out on foot or in vehicles.

- **Monitoring Protocol for Forest Elephants**
- **Populations / areas to be monitored**

All elephant range areas in **Forested ecosystems**; (Aberdares National Park, Aberdares (Outside), Boni and Dodori National Reserve, Arabuko Sokoke, Kipipiri Forest Reserve, Loroki Forest, Mau Forest Complex, Mt. Elgon National Park& Reserve, Mt. Kenya National Park & Reserve, Meru North Dispersal Area, Trans-Mara Forest.

- **Frequency of surveillance**

Frequency of surveillance is solely dependent on what objectives parameters are to be met assessed but ideally it is biannually, repeated after every three two years.

- **Survey method**
- **Dung-count based methods**

There are two main methods based on dung counts for estimating population density and size; 1) **Fecal Standing Crop (FSC) methods and 2) Fecal Accumulation Rate (FAR) methods**. FSC methods measure the rate of dung pile accumulation between two points in time. This is achieved by making two visits to the same plots or transects and counting the number of piles deposited since the first visit, provided the interval between the visits is shorter than the most rapidly decaying dung pile's lifetime. Animal abundance can be calculated from fecal accumulation rates and the mean defecation rate over the period of accumulation. FSC methods in contrast determine dung pile density and relate this to dung decay rate and mean defecation rate (Neff 1968; Putman 1984; McClanahan 1986; Buckland et al 2001; Laing et al 2003; Campbell et al 2004; Smart et al 2004; Walsh and White 2005; Jenkins and Mainly 2008). FSC methods do not require repeat visits hence are less costly and time consuming, making it more favorable compared to FAR methods. Therefore, we herein describe FSC on line transect as a method to estimate elephant numbers.

Dung Decay rate: Dung surveys require data on the abundance of dung piles, defecation (dung production rates and dug ple decay rates. Many surveyors have not assessed dung decay rate at their sites, instead they have used from other sites, though decay rates might be highly variable in different sites and seasons (Barnes and Barnes1992). Inter-site differences and rainfall regime and elephant diets (especially the fruit content of the diet), and probably vegetation types prevent simple extrapolation between sites and seasons.

There are both prospective and retrospective approaches to monitor dung decay, where in prospective approach, dung is monitored till it disappears (Laing et al., 2003), while in retrospective approach calls for the surveyor to locate cohorts of fresh dung piles by making a number of visits to the area prior to the survey.

MIKE dung surveys must use the retrospective method of estimating dung decay rates (Laing et al., 2003). Use of the retrospective approach means that it is essential ti start to conduct decay experiments prior to every survey at every survey site.

Previous knowledge local or studies in the site should be used to estimate the time it takes for elephant dung piles to completely disappear. Begin monitoring dung pile decay rates t months prior to the mid-point of the line transect survey. If there are ni data on dung pile decay rates for the site, start monitoring dung pile decay a minimum of 12 months prior to the mid-point of te line transect survey.

Plan for a minimum of 6 equally spaced visits to the survey area, with the final visit timed to coincide with the midpoint of the line transect survey. At each visit, locate, classify and mark a minimum of 20 fresh dung piles, where fresh dung pile means dung under 48 hours of age. Number of boli per marked dung pile should be recorded.

Dung piles should not be fenced off or otherwise protected from trampling or disturbance. They should be left as they were found.

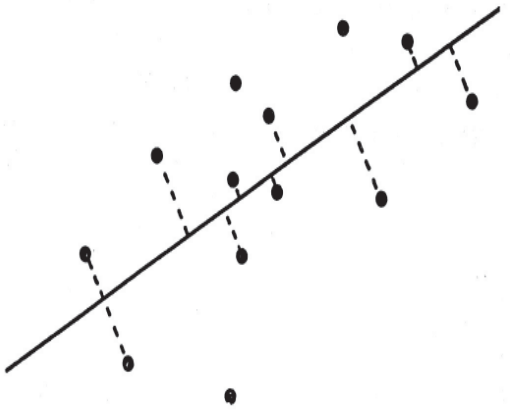
All fresh dung piles located and included in the monitoring program should be identified using a unique reference number, which is recorded on the appropriate datasheet and on a marker pin that is pshed into the ground next to the dung pile. GPS coordinates for each dung pile should be recorded on the datasheet.

Logstic regression methods to estimate the probability of dung file decay function of time. This method requires a single follow up visit, timed to coincide with the mid-point of the line transect survey, to establish whether the dung piles are still present or have disappeared.

Pilot survey: Having decided to conduct a survey, there is a great temptation to leap in and begin collecting data at once. However, it is essential to make a reconnaissance or preliminary investigation first, and then plan the survey carefully. The reconnaissance will show you how elephants are distributed within your study area, and therefore how it should be stratified. It will also reveal the logistical and practical problems you are likely to face. During the reconnaissance you should visit each of the major vegetation types in the census zone. You should also examine the major geographical features (rivers, valleys, roads, villages, mountains, etc.) as these will all affect your planning of the census. All your reconnaissance work will, of course, be conducted on foot. Use a pedometer to give an approximate measure of distance walked. To obtain a rough index of dung-pile density in each area, record all the droppings you see in a one-metre band on either side of you. This will enable you to gauge the relative abundance of elephants in different parts of your census zone. The importance of a reconnaissance before you plan the census cannot be over-emphasized. A reconnaissance can save you an immense amount of wasted effort later. If you are new to a forest, then as a rule of thumb, you should spend not less than 10% of the time allocated for the whole census in

conducting the reconnaissance. The reconnaissance should be followed by several days at your desk when you plan the stratification, layout of transects, and the organization of personnel, equipment and logistics. Then, having satisfied yourself that these plans fit within the limits of your budget, you can set off to cut the first transect.

- **Main survey:**



Transects are walked, with the aid of a pedometer to measure distance walked. The observer walks along the centre-line of the transect (—). Whenever a dung- pile is spotted, it is recorded. The perpendicular distance from the transect line to each dung pile is measured and recorded. The length of the transect can be measured with a surveyor's chain or with a topofil (called a "hip chain" in the USA), which is more practical but less accurate. Each dung pile encountered is classified (A-E) by the shape and age as established by Barnes & Jensen 1987 i.e. the probability of being detected. Thus the morphological stage of each dung-pile should be recorded.

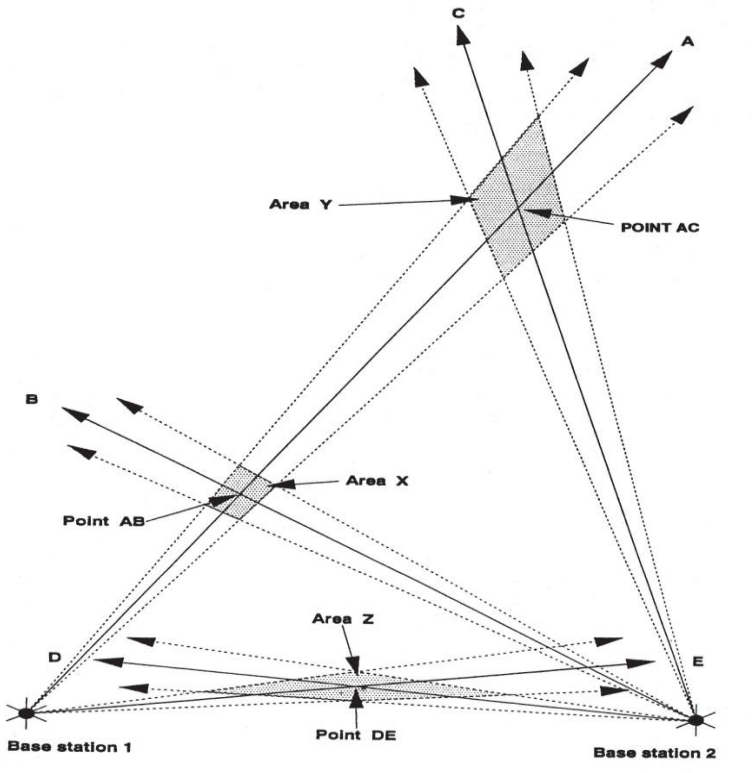
Transects should be approximately 1 – 5 km long depending on habitat and can be randomly located within each strata or arranged in clusters along short baselines, with the clusters randomly located within strata. The number of transects will depend on the size of each strata.
Aerial total counts: Please refer to the aerial mammal count monitoring protocol



Radio and satellite tracking: A) Radio-tracking involves putting a small radio transmitter attached to a collar or harness on an elephant. The transmitter emits a pulsing signal on a predetermined frequency which can be detected on a radio receiver set to the same frequency. The signal is detected through a directional (Yagi) antenna attached to the receiver set to the same frequency, which in turn emits an audio signal through a speaker or headphones. The strongest signal is received when the antenna is

directed straight at the transmitter. Most radio tracking is done using 'conventional' collars, which transmit very high frequency (VHF) radio pulses. Animals are located by 'homing', or by 'triangulation' from the ground, or from aircraft, using directional aerial and purpose-built radio-receiving equipment in line-of-sight of the transmitter.

In the use of triangulation to ascertain the animal position, the observer pinpoints his own position on a map and then determining the compass bearing of the source of the signal. A line can then be drawn on the map from the observer's position through the source of the signal (Point A). By doing this from two (from Base station 2 through Point B) or more points in quick succession, an estimate of the position or a "fix" of the study animal can then be made. This will be where the lines on the map converge (Point AB). The true direction of the animal can always be expected to be a few degrees either to the left or right of the bearing taken, and although the plotted position will be at the point of intersection of these two bearings (Point AB), the animal may be anywhere in the shaded area X. Triangulation is most accurate when the bearings from the two receivers intersect at about 90 (Area X in figure below). As the angle of intersection either increases (Area Z) or decreases (Area Y) from the ideal 90, the potential for error will increase. In other words, as the study animal approaches the line between the two receivers (Point DE), precision diminishes. Also, the farther the animal is from the base stations (Point AC), the smaller will be the angle between the bearings from the two receivers, which also reduces precision (Fairall, 1980).



B) Satellite radio tracking is a relatively new technology which improves the logistics of data acquisition by circumventing many of the deficiencies encountered with conventional radio telemetry techniques. Factors such as hazardous weather conditions, darkness, international

boundaries, remoteness and extensive animal movements do not hinder the systematic collection of data (Fancy et al. 1987). Coded radio signals are sent out from the transmitter, or platform transmitter terminal (PTT), on the elephant, at intervals of typically 60-90 seconds. As an orbiting satellite passes over a transmitting PTT it may detect some of these signals. If a sufficient number of signals are received during the course of a satellite overpass, the satellite can calculate the location of the PTT.

C) GPS collars are now being extensively used where an inbuilt GPS records the position at a set time interval. Data is then downloaded either via a satellite link or UHF receiver on the ground.

D) Occupancy and distribution based on spatial detection-non-detection sampling (camera trap, transect or community-based surveys): Refer to the camera trap and transect based survey protocols

E) Fecal DNA sampling: Non-invasive DNA-based capture–mark–recapture (CMR) methods have been developed to estimate population size and other parameters and have the advantage that samples can be collected without the need to see or disturb the animals. DNA-based CMR methods can provide more precise abundance estimates, and more data about population structure and dynamics, than dung density-based methods. Fecal DNA-based CMR methods may also require less time in the field and can be used when dung density methods are impracticable. Finally, fecal DNA based CMR methods are now cheaper than dung density-based methods when line transect survey costs are approximately equal to CMR survey costs and dung decay rate monitoring costs are greater than laboratory costs (Hedges, 2013).
A pilot survey should first be conducted to (1) assess whether fresh dung-piles could be found in adequate numbers; (2) determine whether sample preservation techniques are appropriate; (3) select loci likely to be informative for the population surveyed; and (4) help design the CMR survey. The CMR survey should have three or more sampling sessions; lengths of sessions can vary due to logistic factors, but search effort should be approximately equal across sessions. Capture rates should be maximised by focusing on areas in which elephants are likely to be found ('hotspots' such as salt licks and waterholes) while also spacing sample collection so that every elephant's home range would contain at least 2–3 collection locations. Distance between sample collection locations must be small if home ranges are expected to be small; if home ranges are large, the distance between sample collection locations can also be relatively large. Sample collection locations need be placed to provide full spatial coverage of the survey area in each sampling occasion, ensuring exposure of all elephants present to potential 'captures. For home ranges of 200–500 km^2; sample collection sites can be between 5-10 km^2 each containing one or more 'hotspots'. Locations need to be sampled at approximately 4-week intervals. All dung-piles sampled should be destroyed afterwards to prevent accidental re-sampling. For each sample, approximately 10 g of dung is placed in a 40 ml polypropylene tube, boiled for 15 min, and preserved in Queen's College Buffer [20% DMSO, 100 mM Tris pH 7.5, 0.25 M EDTA, saturated with NaCl]. Samples are stored in the dark at room temperature before shipment to the laboratory.

- **Timing of surveillance / observations**

1. Dung-count, feacal DNA-based CMR and occupancy-based methods; seasonal and maybe replicated after every three years to establish population trends.

2. Radio and satellite tracking; Continuous

- **Potential causes of bias and rules for standardization**
- **Dung-count based method**

a. The tendency of some elephants to walk while defecating means that some boli might fall in one pile and the rest in another, and might be difficult to establish if assessment is conducted after boli have reached stage D. In this case, the observer should record that and conduct two separate analyses (one assuming that a single pile and the other assuming different piles).
b. Seasonal variations in decay and defecation rates which can be overcome by conducting assessments in the same season.
c. Detection of dung piles on or very close to the transect line. Overcome by clear definition of the transect line and acuity.
d. Error in measurement of perpendicular distance. Overcome by clear definition of transect line and accurate distance measurements

- **Fecal DNA-based method**

a. Assumption of population demographic closure. Overcome by short survey duration
b. Assumption of population geographic closure. Overcome by ensuring the survey area encompassed the entire elephant seasonal range.
c. Sufficient genotypic information. Overcome by ensuring adequate sample size.
d. **Radio and satellite tracking:** directional or geometrical triangulation inaccuracies/errors.

- **Sampling methods**
- **Temporary or permanent sample location:**

1. **Dung-count based method:** Temporary sampling transects randomly placed or in clusters which are randomly placed. The use of permanent transects is discouraged due to a number of limitations and biases as described by Barnes 1996; Buckland et al. 2001; Nchanji and Plumptre 2001; Hedges, Tyson 2002 and the CITES MIKE program's dung survey Tusk Force.
2. **Fecal-DNA based method:** Temporary sampling locations that maximize capture rates by focusing on areas in which elephants are likely to be found ('hotspots' such as salt licks and waterholes) whilst also spacing sample collection so that every elephant's home range contains at least 2–3 collection locations. Sample collection locations should be placed to provide full spatial coverage of the survey area in each sampling occasion, ensuring exposure of all elephants present to potential 'captures'.
3. **Radio and satellite tracking:** selection of animals is needs driven

- **Number of samples**

1. **Dung-count based methods:** Number of transects should be proportional to the variance to be expected in each stratum. In the absence of data of the study area, the optimum transect length is 5 km for the stratum (Barnes et al 1988). Ideally, a minimum of 60-80 dung piles in each stratum is recommended (Buckland et al 1993)

2. **Fecal-DNA based method:** Sample size should be large enough to provide sufficient genotypic information and spatial coverage of the survey area exposing all elephants present to potential 'captures.

- **Personnel responsible and time required**

1. Ecologists / field scientists (survey planning and implementation)
2. Statistician (survey planning and data analysis)
3. GIS analyst (survey planning and data analysis)
4. Guides and security personnel (field surveys)
5. Elephant coordinator (full time)
6. Veterinary and capture unit for fitting transmitters (planning and field work)
7. Genetic laboratory technician (DNA analysis).

- **Equipment required**

GPS units, cameras, pedometers, hip chain, steel and plastic tape measures, DNA kits, collars, receiver antenna, software (ArcGIS, DISTANCE etc.)

Metal stakes, hammer, flagging tape, permanent marker pens, sighting compass, dung classification field reference sheetclinometer and vegetation classification field reference material.

- **Data recording and storage**

Original data recording forms should be safely stored in hard and soft copy within each field office and the data entered into a standard database and sent to the KWS Ecological Monitoring Database and IDS.

- **Data analysis**

Dung-count based methods: Dung piles in E age stage are not used in density analysis. Analytical programs such as TRANSECT (Burnham et al*.* 1980) and DISTANCE (Laake et al*.* 1993) will read perpendicular distances and calculate f (0). This is an estimate of the reciprocal of the effective strip width (ESW). This is defined as the perpendicular distance for which the number of dung-piles missed between the line and the ESW is equal to the number of dung-piles beyond the ESW that are detected. Thus, dung pile density Y is:

$$Y = \frac{n.f(0)}{2L}$$

Where **n** is the number of droppings and **L** is the total length of transects. The methods for estimating the variance of **Y** and the confidence limits are given by Bumham et al*.* (1980) and Buckland et al. (1993). Calculations are done automatically by the programs ELEPHANT and DISTANCE.

The data should be analyzed separately for each stratum, and then combined to give an overall dung-pile density estimate for the whole study area (Norton-Griffiths 1978). The number of elephants (E) is then calculated from the dung-pile density (Y), the defecation rate (D), and the decay rate (r) by the equation (McClanahan 1986; Barnes & Jensen 1987):

$$E = \frac{Y.r}{D}$$

The individual variances of Y, r, and D each contribute to the variance of E. This variance can be calculated in three different ways (Barnes 1993). To obtain an estimate of the mean number of dung piles per elephant available to the observer during the survey period, one must estimate mean dung pile production rate (defecation rate) per elephant per time period. One must also estimate mean dung pile lifetime or decay rate. The mathematics of the relationships among animal abundance and animal sign (e.g., dung pile) abundance via sign creation and survival probabilities are discussed in detail by Buckland et al. (2001: 182–185) and Buckland et al. (2004: 377–385).

Elephant size (a proxy for age) can be estimated from dung bolus size (e.g. Jachmann and Bell, 1984; Reilly, 2002; Tyson et al., 2002).

Fecal-DNA based method: Please refer to Hedges et al 2013 for details on DNA extraction and genotyping methods.

- **Radio and satellite tracking**

a. **Analysis of elephant and other species movements:** Patterns of movement (mean distance travelled etc.).
b. **Analysis of home range:** Grid cells, minimum convex and sorted polygons, probabilistic methods such as kernel based estimates.
c. **Inferring use of habitat and behaviour from movement data:** Suitable where other biophysical information is available (which is the case in most elephant range areas) and human-elephant conflict analysis

- **Reporting procedures**

a. Status reports (inc. IUCN SSC African elephant specialist group figures) and publications

- **Indicators**

a) Elephant abundance and density estimates, distribution and trends
b) Elephant home ranges, seasonal and/or periodic long-distance movements
c) Foraging behavior and spatial use of resources
d) Specific management questions (e.g. which elephant herds frequent which areas?)
e) Dynamic relations between elephant clans, herds and individuals
f) Human-elephant conflict mitigation

- **Institutional collaborations**

CITES/MIKE, IUCN, Local and international NGOs

- **Data recording forms**

- **Dung-count based method data form**

Date:			Weather:		Location:				Page…of …
Start Point (UTM):					Stop point (UTM):				
Start time			Stop time:		Compass bearing:				
Recorder & team members					Transect length (KM):				
Distance from start (M)	Dist.	WP No.	UTM Coordinates		Dung pile data				Elephant sign
			Northings	Eastings	Perpendicular distance	Decay stage*	Number of boli	Circumference	

*Decay stage description

Class	*Description*
A	Boli intact, very fresh, moist, with odour
B	Boli intact, fresh but dry, no odour
C	Some of the boli have disintegrated; others are still recognisable as boli.
D	All boli completely disintegrated; dung-pile now forms an amorphous flat mass
E	Decayed to the stage where it would be unlikely to be detected at a range of two metres in the undergrowth

- **Elephant dung pile decay rate monitoring datasheet**

Date					Data entered to Computer (Y/N)							Location		Page…of …	
Obervers												Computer file name(s)			
Dung pile ref Number	Date found	Number of boli	Dung pile moved (Y/N)	Location (GPS)	Veg type	Slope	Altitude	#1 *	#2 *	#3 *	#4 *	#5 *	#6 *	#7 *	#8 *

*Information to be recorded for each dung pile: No. of days since dung was originally found, date, if found in subsequent visits and stage it was found for the first and last visit

- **Monitoring Protocols for Large Carnivores**
- **Monitoring objectives**

1. Large carnivores are situated at the highest trophic level. Because they depend on a whole suite of potential prey species, they are:
   i. Naturally rarer than species at lower trophic levels, resulting in the majority of species being listed in high threat categories in the IUCN Red List (see below), and
   ii. Good indicator species for overall ecosystem health.
2. Large carnivores are prone to conflict with humans, mainly through livestock depredation. Therefore, even where natural prey is abundant, large carnivore numbers can be depressed through retaliatory killing by herders. Without direct population monitoring, this cannot be detected.

Large carnivores, and in particular lions, are flagship species, also for wildlife tourism. Monitoring population status is therefore vital also from an economic standpoint, as healthy populations of lions and other large carnivores can generate considerable income through tourism.

- **Conservation objectives**

To at least maintain the current range and population size of the six listed species (see above) over the next 10 years.

- **Populations / areas to be monitored**

All priority populations in Kenya, as outlined in the national conservation and management strategies for large carnivores in Kenya (KWS 2009, 2010).

Table xx: Priority Large Carnivore Species in Kenya- Protected under Wildlife Conservation & Management Act 2013

Species	**IUCN Threat Category**	**CITES Appendix**	**Legal Status in Kenya**
Lion (*Panthera leo*)	Vulnerable	Appendix II	Protected
Cheetah (*Acinonyx jubatus*)	Vulnerable	Appendix II	Protected
Leopard (*Panthera pardus*)	Near Threatened	Appendix I	Protected
Spotted Hyaena (*Crocuta crocuta*)	Lower Risk/Conservation Dependent	Not Listed	Protected
Striped Hyaena (*Hyaena hyaena*)	Near Threatened	Not Listed	Protected
African Wild Dog (*Lycaon pictus*)	Endangered	Appendix I	Protected

- **Frequency of surveillance:** At least every three years.
- **Survey Methods**

There are two main traditional methods, now complemented by emerging technologies:

I. Using systematic track counts.
II. Using call back stations.
III. Using emerging technologies

- **Survey Methods: Using Systematic Track Counts**

Survey methods commonly used for African savannah mammals, such as aerial surveys or line transects, typically yield few observations of large carnivores, which occur at low densities, are predominantly nocturnal, and can be secretive (Burton 2012). Consequently, prior efforts to establish large carnivore occurrence and/or abundance over large spatial scales relied on interviews (Gros 1998), remote cameras (Pettorelli et al. 2010), or track surveys (Thorn et al. 2010). To establish and monitor population size within discrete protected areas, call-ups (see Ogutu & Dublin 1998, and the call-up survey protocol in this document) yield reliable results for lions and spotted hyaenas, while systematic track counts (see Funston et al. 2010) produced reliable results for lions, leopards, cheetahs and hyaenas. In this section we focus on systematic track counts.

Most large carnivore species exhibit extensive movements along man-made roads, and recent studies comparing the effectiveness of different large carnivore survey techniques identified the use of spoor transects along dirt roads as the most appropriate method in terms of detection efficiency, effort, and cost (Thorn et al. 2010). Further, studies identified strong linear relationships between large carnivore population densities and track-based abundance indices derived from spoor transects, thus establishing spoor transects as a robust means to predicting large carnivore densities (Stander 1998; Funston et al. 2010). This approach permits the application of cost-effective spoor transects to assess large carnivore distribution and population size within an area of interest (see Ferreira et al. 2013).

The preparations for this method involve a prospection of the study area by vehicle to GPS track-log available roads and assess the suitability of those roads for spoor transects, which require relatively fine substrates. The study area is then divided into grid cells of 15 by 15 km size. In each cell, a road section of 20 km length and with suitable substrate is selected as a spoor transect.

Transects are covered early in morning, to assure that any tracks left by large carnivores during the course of the night would still be visible, and that no other vehicle could have passed along the road prior to the survey team. Transects are vehicle-based, with two observers seated on the bull-bars or customized seats on the bonnet of a survey vehicle. The vehicle is driven at a

maximum speed of 10 km/h, to assure that the observers can easily detect large carnivore tracks. Survey teams are equipped with a GPS unit. At 500 m intervals along transects, as measured with the GPS trip odometer, the survey team notes the quality and type of the road surface. Collection of this information is vital, as the probability of detecting tracks ultimately depends on the quality and type of the road surface (Funston et al. 2010). The collection of reference points on road surface quality permits the assessment of average surface quality for each transect, which in turn permits an evaluation of the impact of average transect surface quality on large carnivore detection probabilities. While road surface type can simply be assigned to broad categories (e.g. sandy, clay-rich, etc), values between 1 and 4 can be assigned by the observers for substrate quality.

Prior to the survey, all team members should be thoroughly trained in the recognition of large carnivore spoor, and each team should carry a field guide for the identification of large carnivore tracks (see Appendix). When available, expert indigenous local trackers should be used as observers. When tracks are found, the vehicle stops and trackers identify the species, discounting any that is not reliably identified. Only fresh tracks (<24 hours old) are recorded, following Funston et al. (2010). For each new set of tracks, a photo should be taken with a photometric scale placed next to the track, to permit a quality control of species identifications and of track age assessments. As with observations on road surface quality and type, the team marks a GPS point for all spoor records, and notes the reference of this point, the distance from the transect start point, time, large carnivore species, the number of individuals, and the reference of the photo taken (as shown on the camera display) in a data sheet (see Appendix xx). For lions and leopards, experienced trackers may be able to distinguish between tracks of males and females, and this information should also be noted.

To minimize the risk of double-counting large carnivore individuals, observers should try to carefully asses, based on track age, number of individuals, direction of travel, and distance between track records, if a spoor detected represented a new individual, or an individual already recorded which followed the road. In case observers find two similar spoors within 500 m of one another and cannot identify these individually, Funston et al. (2010) recommend only counting one spoor set, to reduce the risk of double-counting.

For each transect, the number of track observations for each species is calculated, and transformed into “track densities”, i.e. the number of tracks per 100 km of transect. This large carnivore track density is strongly and positively correlated with large carnivore population density in any given area (Funston et al. 2010). Based on this observed correlation between track density and “true” large carnivore density, track densities can therefore be transformed into population densities (see below).

- **Survey Methods: Using Call Back Stations**

Certain calls are known to attract carnivores in general. A combination of these sounds can be played from repertoires of tape-recorded vocalizations. These may include:

a) Bleats of a dying wildebeest calf
b) Distress call of a buffalo calf
c) Hyenas mobbing lions
d) Hyena inter clan fight
e) Hyena squabbling at a kill
f) Pig squeal
g) Lion roar

The call-in stations are set up in a study area randomly; This involve dividing study area sampling points of 10km by 10km grids and each grid intersection assigned a number. Each grid intersection is taken as potential call-in station. The call-in station is approached by a vehicle in late evening and at night where the car is parked in a spot with good visibility in proximity to the given coordinates as much as possible.

The speakers are mounted on top of a hard-top land cruiser at a height of 2.4 m above the ground. Vocalizations at each call-in station are broadcasted interspaced with five minutes breaks of silence. During the break, the station is searched using a combination of night visions and powerful spot lights for responding carnivores and recorded accordingly.

- **Carnivore density is estimated by:**

a) Multiplying the number of call-up stations by the estimated sampling area to estimate the total survey area
b) Dividing the number of individuals responding to the call-ups by the area sampled
c) Dividing by the probability of lions responding during calibration call-ups.

Finally, these density estimates are multiplied by the total area of study area to estimate the total number of adults, using the cub-to-adult ratio from known results from the area or other research findings in the area to estimate total population size.

- **Standard Survey Methods: Focus on Robust Density Estimation via SECR**

Prior efforts relying on traditional survey techniques, such as aerial surveys or line transects, typically yielded few observations of large, secretive, and nocturnal carnivores. Therefore, the required standard method must shift away from producing relative abundance indices toward generating unbiased estimates of density, abundance and space use, which are critical metrics for assessing population status and impact. The Spatially Explicit Capture-Recapture (SECR) framework is the mandatory replacement for traditional index-based methods, offering transparency, reliability and the ability to integrate spatial covariates into model-based inference.

- **Method A: Spatially Explicit Camera Trapping (SECR)**

SECR is the preferred method for monitoring species that are individually identifiable via natural markings (e.g., Leopard rosettes, Cheetah spots) or artificial markings (e.g., GPS collars on Lions or Wild Dogs).

- **SECR Principles and Applicability**

The SECR model revolutionizes traditional capture-recapture by explicitly modeling the probability of detection. It defines this probability as a function that decreases with the distance between the detection device (camera trap) and the individual animal's activity center (the center of its home range). This statistical rigor means that SECR overcomes the significant bias inherent in older methods that required the imprecise calculation of an "effective sampling area". By collecting georeferenced individual identification data alongside survey effort, SECR ensures that estimates of population density are robust and reliable.

- **Field Deployment and Array Design**

Successful SECR relies on a standardized, systematic deployment of monitoring devices across the entire study area. Opportunistic sampling is unacceptable as it introduces significant bias.

Standardized Grid Layout: Camera traps must be placed on a pre-determined grid. The spatial arrangement of the trap locations relative to the estimated movement radius of the target species is paramount. For large carnivores, camera spacing should be optimized, typically set at 1–2km apart.

Trap Site Configuration: To maximize the chances of detection and identification, camera traps are generally set perpendicular to animal trails, paths, or linear features (like dirt roads) commonly used for movement, positioned approximately 2 meters away. The camera height must ensure the target animal is captured clearly.

Paired Camera Mandate: For species requiring identification based on bilateral markings (e.g., Leopard rosettes, Cheetah spot patterns), camera traps must be deployed in opposing pairs at a single site. This configuration dramatically increases the chance of capturing clear side images of both the left and right flanks, which is critical for accurate individual recognition.

Effort Requirements: To ensure statistically robust data, monitoring requires substantial effort. The minimum recommended effort is ≥160 trap sites, aiming for 250–300 camera days per study to provide sufficient capture histories for density estimation.

- **Camera Specifications and Data Acquisition**

Field teams must utilize modern, reliable camera traps with fast trigger and recovery speeds, and wide fields of view. Equipment should be housed in durable, protective shells resistant to potential animal interference. All deployment must be precisely georeferenced using high-accuracy GPS units, recording essential metadata: Trap ID, GPS location, Start/End time, and specific environmental covariates.

A major logistical challenge in camera trapping is the intensive labor required for processing the large volume of images. To address this, current protocols require the integration of emerging technology, specifically advanced Artificial Intelligence (AI) tools (e.g., TrapTagger), which are capable of classifying images to the species level. This automated preprocessing significantly reduces the time and cost associated with manual photo classification, making large-scale monitoring efforts more practical and efficient.

- **Survey Methods: Emerging Technology-Based Approaches**

Emerging technologies can enhance the accuracy, efficiency, scope, and cost-effectiveness of large carnivore monitoring and are encouraged for use alongside traditional methods by WRTI, researchers, NGOs, and community-based organizations.

1. **Camera Trapping with AI-Assisted Processing:** Grids of motion-activated infrared camera traps provide continuous, non-invasive monitoring. Artificial Intelligence (AI) software (e.g., MegaDetector, Wildlife Insights) can automatically filter empty images and classify species, enabling robust population estimates via Spatially Explicit Capture-Recapture (SECR) models for identifiable species (Norouzzadeh et al., 2018). Widely used in Laikipia, Mara, and Tsavo.
2. **Satellite and GPS Telemetry:** GPS-GSM or satellite collars provide near-real-time data on movement, home range, and mortality alerts. Critical for conflict mitigation and understanding ecology. Integrated platforms like *EarthRanger* facilitate real-time spatial monitoring (Kays et al., 2015).
3. **Environmental DNA (eDNA):** Detection of species via DNA in water, soil, or snow samples. Highly sensitive for elusive species and allows metabarcoding for biodiversity assessment. Pilot studies are underway in Kenyan riverine systems (Bohmann et al., 2014).
4. **Acoustic Monitoring:** Autonomous audio recorders capture vocalizations. Machine learning algorithms (e.g., BirdNet) can automate species call identification, useful for density estimation and behavioral studies (Heinicke et al., 2015).
5. **Drone (UAV) Surveys:** UAVs with high-resolution or thermal cameras cover large, inaccessible areas. Thermal imaging is effective for nocturnal counts. Requires KCAA approval and careful use to minimize disturbance (Mulero-Pázmány et al., 2017).
6. **Citizen Science & Mobile Platforms:** Engaging the public via apps (e.g., Mammal Atlas Kenya, iNaturalist) increases observational coverage and public engagement (Dickinson et al., 2012).
7. **Remote Sensing & Habitat Modelling:** Satellite imagery (Sentinel, Landsat) monitors habitat change and fragmentation. Used with predictive models (e.g., MaxEnt) to map habitat suitability and climate impacts (Guisan et al., 2017).

- **Timing of surveillance / observations**

For Track Counts & Call Back: Dry season, due to improved accessibility and because rain could erase tracks. Counts should be conducted in the early morning hours (6:30-10:30) for good track visibility. Call-back surveys are conducted at night during the dry season.

- **For Emerging Technologies:**

I. **Camera Traps:** Can be deployed year-round; data retrieval and battery checks are easier in the dry season.
II. **Telemetry:** Continuous, year-round data collection.
III. **eDNA:** Sampling is most effective in dry periods when water sources are concentrated.
IV. **Drones:** Best flown in dry, calm weather conditions.

- **Potential causes of bias and rules for standardization**

I. **Seasonal/Temporal Bias:** Timing should be kept constant across survey years. Repeat visits should be in the same season (long dry season).
II. **Weather:** Traditional surveys should not be undertaken in rain or high winds (>15 mph) which can erase tracks or affect sound transmission.
III. **Observer Bias:** Use well-trained and experienced personnel. For tech methods, standardize equipment settings, deployment protocols, and AI model training datasets.
IV. **Double-Counting:** In track counts, carefully assess if tracks are from new individuals. In camera trapping and telemetry, use standardized individual identification protocols and spatial analysis to avoid duplication.
V. **Technology-Specific Bias:**
    a. **Call-back:** Response rates vary by sex, distance from speaker, and territory location.
    b. **Camera Traps:** Placement (trail vs. off-trail) affects detection probability. AI requires validation for local species.
    c. **Telemetry:** Collar deployment can be biased towards accessible individuals.
    d. **eDNA:** Detection depends on shedding rates, environmental degradation, and PCR inhibitors.

- **Sampling methods**
- **Temporary or permanent sample location:**

I. **Track Counts/Call Back:** Ideally, repeat surveys along the same permanent transects or stations.
II. **Camera Traps:** Grids or systematic arrays can be permanent or rotated.
III. **eDNA/ Acoustic:** Sampling points can be randomized or stratified permanently.

- **Method of sample location:**

I. **Track Counts:** Generate grids within the study area and select continuous road sections with suitable substrate in each cell.

II. **Call Back:** Generate grids and assign random numbers to intersections for random station selection.
III. **Tech Methods:** Use stratified random sampling based on habitat types, or systematic grids for camera traps and eDNA points, informed by GIS.

- **Number of samples**

I. **Track Counts:** Ideally, survey all grid cells with roads. If not possible, stratify the area and survey ≥40-50% of cells.
II. **Call Back:** Sample 20-30% of the study area.
III. **Camera Traps:** Density depends on home range size; for SECR, a grid spacing of 2-4 km for large carnivores is typical, covering a representative portion of the habitat.
IV. **eDNA/Acoustic:** Number of points depends on habitat heterogeneity and desired detection probability.

- **Monitoring Requirements**
- **Personnel responsible and time required**

I. Study Design & Analysis: Individuals with knowledge of GIS, statistics, data science/AI analysis, and ecological modeling.
II. Field Survey (Traditional): Team of two expert trackers, a team leader (GIS/navigation), and a driver. Can complete one 20km transect per morning.
III. Field Survey (Technology): Technology Specialist, field assistants trained in device deployment/maintenance, Community Engagement Officer for citizen science.
IV. Security personnel and local experts with indigenous knowledge are valuable for all field operations.

- **Required Equipment**

I. Core Vehicle & Navigation: 4x4 truck, GPS receivers.
II. Traditional Survey: Digital camera, data sheets, spotlight, night vision devices.
III. Call-back: Audio playback system, speakers.
IV. Emerging Technologies:
    a. Infrared camera traps
    b. GPS/Satellite collars and base station
    c. Acoustic recorders (e.g., AudioMoth)
    d. Drones (with thermal capabilities, KCAA-approved)
    e. eDNA sampling kits (filter pumps, sterile containers)
    f. Tablets with offline data collection apps (e.g., Survey123)
    g. Laptop for field data management and charging capability from vehicle
V. Data Storage: Portable hard drives, cloud storage subscriptions.

- **Data recording and storage**

I. Recording: Use standardized digital data sheets on tablets. For tech methods, ensure metadata (GPS, time, settings) is automatically logged.
II. Storage: All raw and processed data must be backed up in the centralized Ecological Monitoring Database at regional and WRTI headquarters.
III. Platforms: Utilize shared, cloud-based platforms where appropriate for collaborative projects:
    a. *Wildlife Insights* or *MammalWeb* for camera trap images.
    b. *Movebank* for telemetry data.
    c. *EarthRanger* for integrated real-time monitoring.
    d. WRTI database for finalized, analyzed results and official reporting.

- **Data Analysis**
- **Analysis for Track Counts**

For each spoor transect, calculate independent track observations per species and convert to "track densities" (tracks per 100 km). Compare densities across strata (vegetation, management regimes). Convert track density (t_i) to population density (x_i) using equations from Funston et al. (2010):

I. Lions on sandy soils: $*x_i = 0.371 + 0.032t_i*$
II. All other species on sandy soils: $*x_i = 0.416 + 0.012t_i*$
III. All species on hard, clay-rich soils: $*x_i = 0.084 + 0.040t_i*$

- **Analysis for Call Back Method**

The number of lions/hyaenas (Y) responding at *k* stations is used to estimate the mean number present (N), assuming a Poisson distribution with mean λ and a binomial response probability π. Density per vegetation cover is: $D = (\hat{\lambda}) / (\hat{\pi} * A)$, where A is the effective sampling area (π * radius^2). Radius: ~3.2 km for hyaena, ~2.5 km for lion. $\hat{\pi}$ estimates: ~61% for spotted hyaena, ~26% for lion (Mills et al., 2001; Hans, 2007).

- **Analysis for Emerging Technologies**

I. Camera Traps: Use Spatially Explicit Capture-Recapture (SECR) models in software like secr or SPACECAP to estimate density of individually recognizable species.
II. Telemetry: Analyze movement paths, home ranges (e.g., Kernel Utilization Distribution), and resource selection using software like adehabitatHR or online platforms like *Movebank*.
III. eDNA: Use bioinformatics pipelines for sequence filtering, clustering (e.g., USEARCH), and taxonomic assignment against reference databases.
IV. Acoustic Data: Use spectrogram analysis and machine learning classifiers (e.g., via Raven Pro or TensorFlow) for automated species detection.

V. Integrated/Habitat Modelling: Use Occupancy modelling to account for imperfect detection from any method. Apply Species Distribution Models (SDMs) like MaxEnt to predict habitat suitability.

- **Reporting procedures**

1. Annual Carnivore Conference presentations.
2. Quarterly/Annual Field Progress Reports to KWS and stakeholders.
3. Scientific papers in peer-reviewed journals.
4. Data uploads to shared national and international databases (e.g., WRTI, GBIF).
5. Community feedback sessions in relevant areas.
6. Biannual Wildlife International Conference

- **Indicators**

1. Number of large carnivore species recorded.
2. Large carnivore population size and density.
3. Large carnivore population trends over time.
4. Changes in spatial distribution and occupancy within the survey area.
5. Key demographic parameters (e.g., cub-to-adult ratios, sex ratios) where possible.
6. Identification of human-carnivore conflict hotspots.

- **Institutional collaborations**

I. Traditional & Research Partners: Panthera, Lion Guardians, Living with Lions, Action for Cheetahs Kenya, Mpala Research Centre, Zoological Society of London (ZSL).
II. Technology & Innovation Partners: WILDLABS (global conservation tech network), Allen Institute for AI, San Diego Zoo Wildlife Alliance, Kenya Civil Aviation Authority (KCAA) for drone regulation.
III. Local Academia: University of Nairobi (Centre for GIS), Jomo Kenyatta University of Agriculture and Technology (JKUAT), National Museums of Kenya.

- **Monitoring Protocol for non-human Primates**
- **Introduction**

Kenya hosts a diverse assemblage of primates occupying forests, woodlands, montane ecosystems, coastal habitats, rangelands, and riparian corridors. Effective monitoring is essential for conservation planning, population management, ecological research, and mitigation of human–primate conflict. This manual provides standardized, Kenya-appropriate methods for primate monitoring aligned with global best practices and local institutional guidelines (WRTI, KWS, KEFRI, NMK, universities, and conservation NGOs).

Target taxa include: - Olive baboon (*Papio anubis*) - Yellow baboon (*Papio cynocephalus*) - Vervet monkey (*Chlorocebus pygerythrus*) - Sykes' monkey (*Cercopithecus albogularis*) - Blue monkey (*Cercopithecus mitis*) - Tana River red colobus (*Piliocolobus rufomitratus*) - Tana River mangabey (*Cercocebus galeritus*) - Colobus guereza (*black-and-white colobus*) - Potto (*Perodicticus potto*) - Galagos (*Galago spp.)*

- **Monitoring Objectives**
- **Conservation Objectives**

I. Assess population size, distribution, and long-term trends.
II. Monitor habitat quality, fragmentation, and connectivity.
III. Detect potential declines and determine causes.
IV. Evaluate success of conservation interventions.
V. Support development of species management plans.

- **Management Objectives**

I. Detect human–primate conflict hotspots.
II. Inform translocation, rescue, or rehabilitation decisions.
III. Assess disease risks at the wildlife–livestock–human interface.

- **Survey Methods Overview**

Primate monitoring uses both traditional field-based methods and modern technology-enhanced techniques.

- **Primary recommended methods**

I. Line transect distance sampling (preferred for forest and woodland primates)
II. Habitat-based encounter rate surveys
III. Nocturnal spotlight surveys (galagos & potto)
IV. Camera trapping
V. Acoustic monitoring (for vocal species such as colobus)
VI. Home-range & behavioural monitoring (focal follows)
VII. Drone-based habitat and canopy mapping
VIII. Genetic monitoring (fecal DNA)
IX. Community-based reporting and Earth Ranger patrol data
X. Human–primate conflict mapping

- **Survey Methods in Detail**
- **Line Transect Distance Sampling**

Purpose: Estimate population density and abundance.

- **Applicability:**

I. Tana River red colobus, mangabey

II. Sykes' and blue monkeys
III. Colobus guereza
IV. Vervet and baboons (in woodland and savannah mosaics)

- **Protocol:**

I. Design random or systematic transects (0.5–2 km each) depending on habitat.
II. Walk transects at 0.5–1 km/hr.
III. Record: species, group size, perpendicular distance to group, GPS point.
IV. Conduct surveys during early morning (06:30–10:30) or late afternoon.

- **Analysis:**

Use **Distance software** or R package **Distance** to model detection functions.

- **Encounter Rate Surveys (Non-distance Sampling)**

Useful in habitats with poor visibility or rugged terrain.

- **Record:**

I. Number of groups encountered per km.
II. Habitat type and disturbance signs.

- **Analysis:**

Plot encounter rates over time to infer trends.

- **Nocturnal Surveys**

Applicable for: - **Galagos** - **Potto**

- **Protocol:**

I. Conduct spotlighting along transects using red-filter spotlights.
II. Record eye-shine height, behaviour, GPS, and distance from path.

- **Analysis:**

Encounter rate estimation or occupancy modelling.

- **Camera Trap Surveys**

Highly effective for cryptic primates, arboreal species, and night-active taxa.

- **Deployment Guidelines:**

I. Cameras spaced 300–500 m apart in forest.
II. Mount 1.5–3 m high for arboreal species.
III. Leave operational for 60–90 days.

- **Analysis:**

I. Occupancy modelling
II. Activity patterns
III. Group composition

- **Acoustic Monitoring**

Useful for species with loud or distinctive calls: - Colobus (roars) - Mangabey (whoops) - Blue monkey

- **Protocol:**

I. Deploy passive acoustic recorders at fixed stations.
II. Use spectrogram classifiers to identify call types.

- **Analysis:**

I. Occupancy
II. Behavioural patterns

- **Behavioral & Home-Range Monitoring**
- **Focal Follows:**

Track identified individuals or groups for: - Activity budgets - Diet composition - Social behavior

- **GPS & Telemetry:**

Limited use (mainly rescue, conflict, or research).

- **Drone-Assisted Surveys**

Useful for canopy structure mapping and locating sleeping sites.

Applications: - Tree-height mapping - Forest fragmentation analysis

Limitations: - Dense canopy reduces detection of individuals. - Requires KCAA approval.

- **Genetic Monitoring (Scat DNA)**
- **Applications:**

I. Identify individuals
II. Assess genetic diversity
III. Detect hybridization (e.g., baboons)

Laboratories: - KWS Forensic & Genetic Laboratory, ILRI and University of Nairobi

- **Community-Based Monitoring & Reporting**
- Tools:

I. Earth Ranger Mobile

II. CyberTracker
III. KoBoCollect

- **Data collected:**

I. Crop raids
II. Roadkills
III. Range expansion or dispersal
IV. Habitat destruction

- **Human–Primate Conflict Mapping**

Common conflict for baboons and vervet monkeys.

- **Data points:**

I. Crop damage reports
II. Livestock predation
III. Property damage

- **Uses:**

I. Identifying hotspots
II. Planning mitigation (fencing, deterrents)

- **Sampling Design**
- **Stratification:**

I. Habitat type
II. Elevation zones
III. Protection status (park, forest reserve, community land)

- **Replicates:**

I. Minimum 20–30 transects per habitat type for distance sampling.
II. 40–60 camera trap stations per landscape.

- **Monitoring Frequency**

I. Forest primates: every 2–3 years
II. Savannah primates: every 3 years
III. Nocturnal primates: annually (rapid monitoring)
IV. Critically endangered species (Tana primates): yearly full monitoring + continuous ranger-based reporting

- **Monitoring Requirements**
- **Personnel:**

I. Primatologists

II. GIS specialists
III. Field assistants and local guides
IV. Rangers trained in SMART
V. Data analysts

- **Equipment:**

I. GPS units or tablets
II. Binoculars
III. Rangefinder
IV. Camera traps
V. Acoustic sensors
VI. Drones (optional)
VII. Datasheets or digital apps

- **Data Storage and Management**

I. WRTI Database
II. Conservancy databases
III. Earth Ranger patrol system
IV. Institutional cloud backups

- **Data Analysis Summary**

I. Distance sampling: Density estimation
II. Occupancy modelling: Habitat use & detection probability
III. Behavioural analysis: Focal follows, activity budgets
IV. Acoustic analysis: Spectrogram matching
V. Genetics: STRUCTURE, adegenet, GENEPOP

- **Indicators for Monitoring**

I. Species richness
II. Population density / encounter rate
III. Group size and composition
IV. Habitat condition
V. Conflict frequency
VI. Genetic diversity
VII. Spatial distribution changes

- **Institutional Collaborations**

I. Wildlife Research and Training Institute (WRTI)
II. Kenya Wildlife Service (KWS)

III. Kenya Forest Service (KFS)
IV. National Museums of Kenya (NMK)
V. Universities (UoN, Egerton, Moi, Kenyatta)
VI. Conservation NGOs (Colobus Conservation, Tana River Primate National Reserve teams, WWF, Nature Kenya)

Table 1: Census methods to be used in different ecosystems in Kenya and species to be counted

Census Method	Census Areas	Species to be Counted	Human Activities to be Recorded
Total aerial census	Key Wildlife Ecosystems; Greater Mara, Amboseli-Magadi, aikipia/Samburu/ Marsabit, Meru, Tsavo, Athi-Kapiti, Yatta, Nakuru-Naivasha ranches, and Lamu-Boni. Shimba Hills-Mwalunganje, Nasalot-S Turkana-Kerio Valley	• Mammals larger than the dik dik and large birds like ostrich and ground horn bills • Total counts for elephants, buffaloes and giraffes. • Estimation of presence and abundance of other larger than the dik dik and large birds.	Cultivated areas, human settlements, livestock, logging, charcoal kilns, poachers' hideouts, and water points among others
	Helicopter counts for small enclosed conservation areas; Ruma and Lake Nakuru National Parks, Mwea National Reserve and Solio conservancy.		
	Marine Ecosystems	Dugongs, whales, Dolphins, Sharks, Sea Turtles	Fishing nets, boats
Sample aerial counts	Northern parts of the country including Garissa, Wajir, Mandera, parts of Marsabit and Turkana.	• Mammals larger than the dik dik and large birds like ostrich and ground horn bills. • Vegetation surveys	Cultivated areas, human settlements, livestock, logging, charcoal kilns, poachers' hideouts, and water points among others
Sample ground Count Census (sweep nets, pitfalls traps, camera traps, citizen science)	Key biodiversity ecosystems (Montane & Forest ecosystems) to complement total and sample aerial including primates in remnants of Tana River Forests, Herpatofauna, invertebrates	All terrestrial wildlife and plant species including Terrestrial birds, Red Colobus and Crested manga bey, insects, reptiles, amphibians	Cultivated areas, human settlements, livestock, logging, charcoal kilns, poachers' hideouts, and water points among others
Carnivore ground census	All wildlife areas	All large carnivore species larger than the jackal	Cultivated areas, human settlements, livestock, logging, charcoal kilns, poachers' hideouts, and water points among others

Census Method	Census Areas	Species to be Counted	Human Activities to be Recorded
Total ground census	Small enclosed conservation areas like Nairobi and lake Nakuru National Parks rhinos, Grevy's zebra, Sable antelope, Hirola antelope, and Roan antelope using developed species-specific monitoring programs including Wetland areas, rivers and swamps	All animal species including waterfowls, reptiles, Hippos, sitatunga	Cultivated areas, human settlements, livestock, logging, charcoal kilns, poachers' hideouts, and water points among others boats, nets, farms around wetlands
Bioacoustics methods	Terrestrial and marine	Estimate abundance of bats and marine animal species	
Under water Visual Census	Marine ecosystems	Under water marine species like corals, sea grass, and macro-algae	Pollution, siltation, bleaching of corals and macro-algae species among others
Remote Sensing and vegetation surveys – quadrats & transects	Terrestrial ecosystems	Land use and land cover changes, Vegetation surveys (woody, herbaceous & grasses	Degraded areas, fires, settlements, infrastructure, and deforestation livestock bomas (occupied and unoccupied), logging, charcoal kilns, poachers' hideouts, water points (pans, boreholes, dams, troughs)

8.3 Wildlife census calendar

A calendar for wildlife census in the country is summarized in Tables 2-4 below for Total Aerial Census, Sample Aerial Census, Marine Aerial Census, and Ground Census for Waterfowls, Birds, Herpatofauna (Reptiles and Amphibian) and Vegetation Surveys.

The total and sample aerial census will be undertaken after every three (3)years and will cover both the dry and wet seasons (Table 2 and Table 3). For each census area, we will strive to have a dry and wet season census each year. This will enable comparison of population size and distribution of wildlife during the dry and wet seasons, resulting to provision of data for long-term monitoring of wildlife during the two seasons.

Table 1: Calendar for Total Aerial Census

Census Area	Months	
	Dry Season	Wet Season
Amboseli-Magadi Ecosystem	October	April
Athi-Kapiti Ecosystem	October	April
Kanyonyoo Ranch	October	April

Census Area	Months	
	Dry Season	Wet Season
Laikipia-Samburu-Marsabit Ecosystem	July	November
Meru Ecosystem	July	November
Lamu-Lower Garissa Ecosystem	September	May
Maasai Mara Ecosystem	November	May
Mwea National Reserve	July	April
Nasalot-South Turkana-Kerio Valley Ecosystem	August	April
Shimba Hills Ecosystem	September	May
Tsavo Ecosystem	February	April
Naivasha Ranches	August	June
Ruma National Park	February	June
Lake Nakuru National Park	January	June
Solio Ranch	December	June
Marine Ecosystem	September	April

Table 2: Calendar for Sample Aerial Census

County	Months	
	Dry Season	Wet Season
Mandera	February	May
Wajir	February	June
Garissa	March	June
Tana River	August	May
Turkana	July	April
Marsabit	March	November
Kilifi	February	April

Ground Census for Waterfowls, Birds, Herpatofauna (Reptiles and Amphibian) shall be done during the wet and dry seasons. Priority census sites shall include Important Bird Area, Species hotspots, Protected Areas (Parks, Reserves and sanctuaries), Conservancies and Ranches. Table 4. Below provides a calendar for all the Ground Census as well as frequency of the census at each site.

Table 3: Calendar for Ground Census

Species	Sites	Census method	Census Period
Elephants	Shimba Hills National Reserve; Aberdares National Park; Mount Kenya National Park & Forest Reseve; Mau Forest Complex; Mount Elgon National Park; Arabuko Sokoke Forest Reserve; Marmanet Forest; Roroki-Kirisia Forest;	Indirect dung count method	January, February, July, August, September (dry season)
Waterfowl Census	Wetland areas (i.e., Amboseli swamp; Lake Nakuru, Lake Epolosaat; Lake Naivasha; Lake Magadi; Lake Jipe; Lake Barigo; Lake Bogoria; Lake Turkana; Lake Kanyamboli; Lake Victoria; The Tana delta; Kesses dam; the 7 forks dams;	Ground counts using binoculars	January (dry season) and November (wet season)
Sitatunga	Sites as outlined by Waweru et al. (2021); See Annex 2	Boat census and walking transects while using binoculars	July
Roan antelope	Ruma National Park	Road counts and individual identification	Daily with weekly and monthly reports consolidated
Sable antelope	Shimba Hills National Reserve	Road counts and individual identification	Daily with weekly and monthly reports consolidated
Rhino	All rhino range except Solio Ranch	Individual identification	Daily, with monthly reports being consolidated and tabulated to account for all rhinos
Mountain bongo	Aberdares, Eburu, Mount Kenya, Mau Forest Complex, Mount Kenya wildlife Conservancy	Camera traps and Individual Identification	Each month with monthly reports from Camera Trap data and Individual recognition method
Grevy's Zebra	Laikipia, Samburu, Marsabit Counties	Citizen Science	January after every two years

Species	Sites	Census method	Census Period
Terrestrial birds	All protected areas, conservancies, ranches and other important bird areas	Use of mist nets along transects	Wet and dry season (appropriate months to be selected depending on where the survey is being undertaken
Red Colobus and Crested Mangabey	Remnants of Tana River Forests	Walking transects	Dry season (July-September)
Herpatofauna (reptiles and amphibians	All protected areas, conservancies and ranches	Pit fall traps along set transects	Wet and dry season (appropriate months to be selected depending on where the survey is being undertaken
Carnivores	All protected areas, conservancies and ranches	Spatial explicit capture recapture method, spoor count, call back method	Dry season (January, February March & July, August, September, October)
Insects	All protected areas, conservancies and ranches	Sweep nest along set transects	Wet and dry season (appropriate months to be selected depending on where the survey is being undertaken
Vegetation surveys (woody, herbaceous & grasses	All protected areas, conservancies and ranches	Transects (woody vegetation) and quadrants (for herbaceous plans & grasses	Wet and dry season (appropriate months to be selected depending on where the survey is being undertaken

- **Monitoring Protocol for Water Birds**
- **Introduction**

Birds are excellent indicators of environmental health with the presence or declines of specific avian species indicating the condition of an ecosystem and signaling improvements or deterioration in habitat quality. They play important ecological roles such as seed dispersal, pollination, pest control and nutrient cycling. Besides their ecological roles, birds also hold significant cultural and economic values. They attract tourism through their vibrant plumage and distinctive calls, and contribute to the overall aesthetic and emotional connection people have with the environment. Therefore, understanding the diversity of birds in a given ecosystem is of paramount importance.

Birds belong to the avian class and are remarkably diverse group of vertebrates that have evolved from reptilian ancestors during the Mesozoic Era, roughly 150 million years ago. Today, an estimated 300 million individual birds representing more than 9,000 species, occupy nearly every terrestrial habitat on earth. Their size varies dramatically, from the towering ostrich (*Struthio camelus*) to the tiny bee hummingbird (*Mellisuga helenae*), the smallest bird in the world. Birds are also unique in the animal kingdom for possessing feathers which are specialized structures made of keratin and play essential roles in flight, insulation, communication, and display.

- **Water bird monitoring**

Water Birds are species that are ecologically dependent on wetlands for at least part of their annual cycle or any birds that inhabit or depend on water bodies (Ramsar, AEWA 2018). They are widely recognized as key indicators of wetland health and habitat quality. Monitoring water birds plays a vital role in understanding the condition of wetland ecosystems, providing crucial information that guide their effective conservation and sustainable management

- **Reasons for Monitoring of water birds**

1. Water birds are reliable indicators of wetland ecological condition as they respond to environmental changes and disturbance
2. Monitoring information will support conservation planning through identification of priority sites and guide in habitat restoration.
3. Fulfil legal, policy and international obligations such as AEWA, CMS and Ramsar which Kenya has ratified to.
4. Regular monitoring can detect any alarming declines requiring urgent conservation interventions.

Aim: The water bird census aims to provide long-term information on the population size, distribution, and habitat use to help in identification of important wetlands and support their effective conservation and management at national and international levels.

- **Monitoring Objectives**

1. To assess abundance, diversity and distribution for the resident and migratory water bird species over time and space
2. To identify key sites, migration stopovers, breeding areas and seasonal movements
3. To assess habitat conditions and identify key breeding and wintering habitats
4. To determine the biotic/abiotic and socio-economic factors causing the observed changes
5. To identify rare and threatened waterfowl species to guide in prioritization of key habitats for protection or restoration
6. To increase public awareness on the importance of water birds and wetland habitats

- **Areas to be sampled**

In Kenya, the water bird Census programme has been ongoing for about 35 years in the Rift Valley Lakes, wetlands around Lake Victoria, natural and manmade wetlands in central Kenya and coastal wetlands. Priority sites for counting include any site designated as Ramsar site, IBA/KBA and any other site with national or global designation because of their importance in the conservation of water birds.

- **Equipment and Materials**

Telescopes, binoculars, GPS, maps, electronic recording devices, camera, tally counter, bird field guide books, field data sheets, note books and pencils

Vehicles, boats

- **Personnel**

Ornithologist (team leader), 4 observers, 1 recorder, security, coxswain

- **Frequency of sampling**

The water bird census is conducted bi-annually during January and July to capture information during distinct periods of their annual cycles for instance the presence of migratory species during the non-breeding season on their wintering grounds.

- **Sampling Methods**

Waterbird census methodologies have developed over time, with a range of approaches being applied to improve the accuracy and reliability of data collection. The application of the methods is influenced by multiple factors, including human capacity, physical conditions and ecological characteristics of the site. Wetland environments pose unique challenges due to its fragile and sensitive nature hence the need to minimize disturbance to the ecosystems. Effective implementation require advance planning, acquisition of appropriate equipment and training of personnel.

The selection of an appropriate waterbird census method is guided by the objectives of the study, species abundance, duration of stay at the wetland and species activity patterns. Other factors include size of wetland, accessibility of shoreline, availability of vantage points, number of personnel and equipment. The most important element of waterbird monitoring methodology is standardization and counters need to ensure that counts are conducted in the same site or sites in the same way on every visit.

This protocol presents various census techniques and highlights their strengths and limitations to ensure an efficient and scientifically robust water bird census.

- **Point count method**

Point counts is a quantitative method and involve observers recording birds seen or heard from a single point (chosen randomly or systematically) for a standardized time period. Birds are most active and visible in the morning so counts should be done between sunrise and about 10 or 11 a.m. The recommended duration for the count is 6 to 12 minutes (choose 6, 9 or 12 minutes as the count time). If more time is required, record the amount of time spend counting birds but try to limit the time to a maximum of 20 minutes. Place the count stations at least 400 m apart to avoid double counting. Observers may restrict attention to birds within a prescribed distance of the station (fixed distance circular plots) although sighting distance might be recorded and used to develop estimates of density (unlimited-distance circular plots)

Point count is a widely used technique for sampling birds across the world due to its effectiveness and easy implementation. This method is efficient for detecting vocal species and is particularly useful during breeding season or when the objective is to estimate bird densities. It allows estimation and comparison of species richness among different habitats, which is particularly useful in guiding restoration and conservation efforts. Some of the limitations relate to detection probability biased by the observer, habitat structure, bird's body size or identification mistakes.

- **Transect surveys (ground and boat counts)**

This involve counting birds while walking or boating along pre-determined transects along the shoreline.

- **Ground counts**

Ground counts are the simplest and most widely used method for waterbird censuses. The counts involve systematic coverage of a site by walking the same predetermined route on each visit and stopping at regular intervals to scan and count birds using binoculars and/or a telescope. Surveys are typically conducted along transects spaced 200-500 m apart, depending on habitat type with the minimum transect length of 100m to ensure reliable detection of birds on the transect line. Counts are conducted at least twice annually, during the breeding season and later in the year.

Routes should be carefully selected to optimize light conditions and minimize disturbance to birds. At tidal sites, ensure counts are made at the same stage of the tide, for instance on high tide to reduce intertidal extent and keeps birds within identification range before roosting. Multiple visits under different conditions may be needed to determine optimal survey timing, and counts should be avoided during extreme weather. Observers should use the best vantage points, divide the site into clearly defined, non-overlapping areas, and begin with a preliminary binocular scan to assess overall numbers and species composition in case of disturbance. Birds are then counted species by species, either individually or in numerical blocks, with repeated scans to improve precision and increase the likelihood of detecting small, inconspicuous, or rare species. A tally counter can be used to speed up this process and minimize errors.

- **Boat counts**

Boat counts involve counting water birds using boats along pre-determined transects along the shoreline. This method is often the most practical and effective method for counting waterbirds at large, remote, or inaccessible sites such as lakes, rivers, coastal wetlands, and mangrove systems, where alternative survey approaches may be unfeasible. By allowing access to extensive areas and covering long distances, boats can sometimes cause less disturbance than observers on foot, although in some situations they can cause more disturbance. Despite their advantages, boat surveys present notable challenges, including a low and unstable viewing platform that limits visibility and often prevents the use of telescopes, slow movement that increases the risk of double-counting disturbed birds, and restrictions imposed by adverse weather or tidal conditions. Nevertheless, boats are widely available, relatively affordable compared to aerial surveys, and remain an indispensable tool for waterbird monitoring in many wetland environments.

- **Aerial surveys**

Aerial surveys entails the use of slow-flying, high-wing aircraft or helicopters to count water birds across large and inaccessible wetland landscapes such as offshore waters and extensive river floodplains. This method provide broad spatial coverage within a relatively short time frame, thus enabling rapid collection of data that would be difficult or impractical to obtain through ground-based methods alone. However, this method is costly and often less accurate in species identification and counting due to the high survey speeds. Aerial surveying is a specialized technique and successful aerial surveys depend on careful planning, complex logistics, efficient recording methods (including use of dictaphones, maps, cameras), skilled pilots willing to fly low and slowly, and observers able to cope with demanding flight conditions.

- **Indicators**

I. Trends in abundance and distribution of water birds
II. Trends in usage of different water bodies by water birds
III. Abundance and seasonality of migrant bird species
IV. Habitat quality and threats

- **Data Analysis**

I. Relative abundance index
II. Species richness and diversity indices

- **Institutional collaborations**

The exercise is implemented by a multi-stakeholder team comprising of National Museums of Kenya (NMK), Nature Kenya, Wildlife Research and Training Institute (WRTI), Kenya Wildlife Service (KWS), County Governments, Conservancies, conservation organizations and volunteers.

Reporting

- Semi-annually
- Annually

- **Water bird census datasheet**

African Waterfowl Census Datasheet
Kenya Datasheet

National Museums of Kenya, Nature Kenya, Wildlife Research and Training Institute, Kenya Wildlife Service

*Wetland:*_____ *Date:*_____ *Section:*_____

Recorder: _____ *Start:*_____ *Stop:* _____

Weather Condition *Record*: % cloud cover, windy, calm, rainy, drizzling, cool, warm, hot, chilly etc.

Comments/Notes: (Include habitat conditions, water levels, difficulties due to weather, disturbance etc.)

All Counters: Please write your full names and addresses below

#	Name	Address	Cell phone	Email

Record Uncommon Species in the Table Below

	Species	Numbers	Totals

N/B: Provide detailed description and sketches for any unusual observation on the back of this form

WATERBIRD GROUP/ SPECIES	SEPARATE TALLIES OR NUMBERS WITH A "+" SIGN	Totals
Examples:		
GREBE		
Little grebe		
PELICANS		
Great White Pelican		
Pink-backed Pelican		

Note: Species listed according to the *Checklist of the Birds of Kenya*, 3rd edition, 1996

- **Monitoring of Terrestrial birds**

Terrestrial birds are species that spend the majority of their lives on land-based habitats such as forests, grasslands, deserts, and urban areas. They depend on these habitats not only for foraging but also for nesting and roosting. Forest birds are a broad category of species that depend on forested ecosystems for their habitat. Forests support the highest diversity of terrestrial bird species, with some estimates suggesting around 75% of all avian species use forests as their habitat. Forest-dwelling birds display a wide range of adaptations, with some living primarily in trees (arboreal) and others ground-dwelling within the forest floor. They utilize the different vertical layers of the forest, from the canopy to the understory and leaf litter, for foraging and nesting.

Monitoring terrestrial birds commonly involves a combination of observational and acoustic field survey methods designed to estimate species presence, abundance, and trends. The choice of method depends on the objectives, the target species' behavior, habitat type, and available resources. Combining multiple methods often yields the most robust and comprehensive results.

- **Methods**

1. **Point Counts**

Observers stand at a fixed point for a set time (e.g., 5-12 minutes) and record all birds seen or heard within a specific distance. This is a standard method, especially for monitoring population trends and species richness.

2. **Line Transects**

In this methods observer walk along a predetermined transect recording all birds seen or heard and distance from the transect. It is useful for covering larger areas and species that tend to fly away easily when disturbed.

3. **Area Searches**

Observers search a defined area for a fixed amount of time, recording all species present. This is a simpler method often used for presence/absence data or species richness estimates.

4. **Timed Species Counts (TSCs)**

In this approach, the observers record all species identified within a fixed time period. The period can be divided into segments for example six 10-minute intervals, with species scored according to when they are first seen with higher points given to early sightings (6 points in the first 10 minutes and 1 point in the last). This method captures both species diversity and relative abundance over time.

5. **Mist netting and bird ringing**

Mist netting involves safely capturing birds in fine mesh nets, taking biometric data such as age, sex, fat levels and applying unique leg bands before release. Recaptures provide crucial information on survival, movement patterns and population demographics.

6. **Passive Acoustic Monitoring (PAM)**

Technological advancements offer effective non-invasive ways to collect data, especially for elusive or nocturnal species, or in difficult-to-access locations. The Passive Acoustic Monitoring (PAM) is a non-invasive method that uses Autonomous Recording Units (ARUs) placed in the field to capture bird vocalizations over extended periods.

These recordings are later analyzed either manually (using spectrograms) or automatically using software and AI to identify species calls. It can also give an indication of species abundance, and monitor temporal patterns such as daily or seasonal activity. PAM is especially effective for detecting elusive, nocturnal, or vocal species and allows large-scale, long-term monitoring with minimal disturbance to birds and their habitats.

7. **Other technology assisted methods**

Technology-assisted methods for monitoring birds use a range of complimentary tools to study population trends, movement and habitat use. Radio telemetry uses small transmitters to monitor short-range movements, while satellite tracking and geolocators are effective for documenting long-distance movements and migration patterns. Camera trapping helps in detecting ground-dwelling, rare, or elusive species that are difficult to observe directly. Citizen science programs harness data collected by volunteers through standardized surveys and mobile apps such as eBird to provide large-scale information on bird distribution and population trends.

8. Counting nesting colonies

Many bird species nests in colonies, making them relatively easy to count during the well-defined breeding season, with methods tailored to nest type and location. The technique adopted depends upon whether the colony is on a cliff face, or whether the species nests on the ground, in burrows, trees or bushes. The focus is on identifying occupied nests, minimizing disturbance, and accounting for potential biases

For cliff colonies, counts are made from an opposite vantage point directly or through photographs, though visual biases may occur especially on birds with similar colors.Burrow-nesting species are more challenging; sampling using random or stratified quadrats or line transects helps identify occupied burrows by signs such as feathers, droppings, or broken eggs, while avoiding misidentification with other species. Ground-nesting colonies can be counted directly if small, or subdivided and sampled with transects or quadrats for larger colonies, mapping boundaries and using distance sampling to estimate total nest numbers. Tree-nesting colonies are counted from suitable vantage points, noting fresh nesting material or attending adults, with post-breeding counts reducing disturbance. Roosting species, particularly waders and wildfowl, are counted when birds are highly clumped for example at night or during high tide, counting either directly or via flocks entering or leaving the site even though very large roosts may lead to underestimation.

- **Other bird monitoring programmes**

Besides waterfowl census and terrestrial bird surveys, other ongoing bird monitoring programmes in Kenya include, Important Bird Area (IBA)/Key Biodiversity Area (KBA) monitoring, Kenya Bird Map project, Vulture monitoring and Bird ringing programmes all implemented through multi stakeholder approach involving NMK, Nature Kenya, WRTI, KWS, KFS, Peregrine fund, Arocha Kenya and other conservation organizations. Kenya Bird Map project aims to map the current distribution Kenya’s bird species and describe their status using citizen science approach. Bird ringing involve placing a unique numbered ring on a bird's leg, which allows for the tracking of individual birds when they are recaptured or sighted again with the objective of gathering information on bird survival and movement to aid conservation efforts. Increasingly,

automated acoustic recorders and citizen science programs complement traditional surveys by providing long-term, large-scale data on bird distribution and population changes.

- **Monitoring Protocol for Reptiles and Amphibians**

Herpetofauna which includes reptiles and amphibians is a crucial component of biodiversity and play an integral role in ecosystem functioning. Due to their sensitivity to changes in habitat quality and climate, these species act as bio-indicators indicating the health of both terrestrial and aquatic habitats. Furthermore, herpetofauna contributes to ecological balance by regulating prey populations and serving as prey for higher trophic levels.

- **Aim**

To generate timely and accurate information on abundance, habitat preferences and threats to key amphibian and reptile species to support the development of effective conservation strategies.

- **Monitoring objectives**

I. To monitor spatial and temporal trends of herpetofauna especially the endangered species
II. To generate data on ecologically sensitive species, particularly amphibians as early warning tools for environmental changes
III. To collect herpetofauna species occurrence data to support large-scale environmental change modeling.

- **Populations / areas to be monitored**

The herpetofauna motoring will target all Protected Areas and other biodiversity hotspots hosting threatened species some of which are highlighted below:

I. Sagalla Caecilian *Boulengerula niedeni* (IUCN, CR): Sagalla Hill, Taita Hills (Coast Conservation Area).
II. Shimba Hills Reedfrog *Hyperolius rubrovemiculatus* (EN): Shimba Hills (Coast Conservation Area)
III. Spiny forest ReedFrog *Afrixalus sylvaticus* (EN): Shimba Hills (Coast Conservation Area)
IV. Irangi Forest Puddle Frog *Phrynobatrachus irangi* (EN): Mt. Kenya-Irangi Forest, Embu (Mountain Conservation Area).
V. Mt. Elgon Torrent Frog *Arthroleptides (Petropedetes) dutoiti* (CR): Mt. Elgon forest: Koitobos & Suam Rivers (Western Conservation Area).
VI. Pancake tortoise *Malacochersus tornieri* (VU): Eastern & Northern Kenya rocky Hills drylands (Nothern & Tsavo Conservation Areas).
VII. Chameleons of the genera *Chamaeleo* and *Kinyongia* (CITES App. II) in the Kenya highlands and coastal lowlands (Throughout distribution range).
VIII. All reptile and amphibian's species assemblages associated with each of the above species.

- **Frequency of monitoring**

The surveys will be conducted twice a year during dry and wet season to understand seasonal variation in species abundance and distribution. Nocturnal sampling will be carried out between 6.30pm and 8.30pm per sampling event. Consistency in the timing (season and time of the day) is required to ensure standardization, reduce any bias and improve precision. It is recommended that the surveys can be done on an annual basis, but a longer interval like biennially can be adopted depending on resource availability.

- ***Observations / data types***
- Direct sightings of species types and abundance
- Species trapping effort and search effort
- Frog advertisement calls,
- Habitat type and status - forest cover and water quality in wetlands, any form of disturbance
- Traditional practices associated with certain species
- Reported cases of killing and/or collections of species

- **Survey methods**

1. **Time-Limited Search (TLS)**

An observer or a group of observers employ a continuous sampling effort within a study area or transect for a limited period of time (Howell, 2002). This method is mostly applicable where animals are more conspicuous, breeding congregations e.g. of amphibians, night-time count of chameleons or sit-and wait predators like geckos. The procedure involves identifying sampling area e.g. a 1 km transect and setting a block of time (mostly 10 – 30 minutes depending on the number of observers to be equivalent to one-person hour). The observer(s) should move slowly, making effort to look at all possible microhabitats to detect species, covering a width of 10m (5m on either side of the line transect). No boundaries are set other than staying within the selected habitat. All the different species and number of reptiles and amphibians found will be recorded noting their sexes and life stages as well as their activity (e.g. resting, basking, mating etc.) if possible. Herps will be counted as they walk, over the ground, hide in crevices, logs, or heard calling or even dug from loose soils (Hoyer et al 1994; Dodd 2003). For purposes of comparison, the number of (experienced) observers, habitat type, time of sampling, local weather, total time spent during sampling should be standardized. The overall time spent is equivalent to number of searchers times the total time spent searching.

2. **Visual Encounter Surveys (VES)**

Searches for amphibians and reptiles are conducted in sites identified at random in each of the habitat types for a defined period of time (20 minutes), stopping to record the observed species, and then proceeding with the searches (Heyer et al. 1994, Sutherland 1996, Rödel & Ernst 2004). The process will involve turning dead logs and rocks, combing through bushes and grasses, as well as checking for arboreal species on trees.

3. Drift-fence and Pit fall traps

This method is usually used to supplement TLS especially for long-term studies. It is mostly effective for sampling in forest floor species e.g. leaf-litter frogs as well as toads and ground moving lizards (Howell, 2002). Various configurations can be employed, e.g. X-shaped or cross-shaped trap lines, Yshaped, or linear, consisting of plastic sheeting (drift fences) and sunken 10-liter buckets (pitfall traps) (Karns, 1986; Sutherlands 1986; Heyer et al 1994; Dodd 2003; Burger et al, 2004; Rödel & Ernst, 2004). The fence (0.5m) is stapled vertically onto wooden stakes while the traps are sunken in such a way that their rims are flush with the ground level and positioned so that the drift fence runs across the middle of the trap. Usually buckets (of about 10- or 20-liters capacity) are placed at 5 m intervals along the array, with one at the intersection. A number of trap lines can be set up within the study site for comparison between habitats.

The traps can be visited twice per day, early in the morning and later at dusk, and all reptiles and amphibians found removed and recorded. In each case all the animals captured, weight and length measurement will be taken and compared between sites. During routine checks, damaged sections are repaired and leaf litter, soil and other debris are removed from the buckets.



Plate .....:A set up of drift fence and pitfall traps (X-configuration).

4. Nocturnal methods

This will target species that are active mostly at night including amphibians and some reptiles. Preselected suitable habitats will be visited between 6.30pm to 8.30pm using maglites. Amphibians breeding areas will be targeted where data on species occurrence, abundance and advertisement calls will be recorded.

Passive acoustic recorders and solar-powered devices like FrogPhone allow continuous or real-time collection of vocalizations, reducing the need for frequent field visits. Collected audio will be analyzed using spectrograms and bioacoustic software, while machine learning algorithms automatically identify and classify species, greatly speeding up data processing. Additionally, citizen science platforms expand datasets through community contributions. Together, these technologies will enable efficient, large-scale monitoring of frog populations, providing critical insights for conservation and ecosystem health assessment.

- **Identification of species**

Most harmless species can be captured by hand and closely examined for identification. Currently, a number of detailed references are available for identification of amphibians and reptiles. The most comprehensive ones include Spawls *et. al.* (2002) for reptiles and Channing and Howell (2006) for amphibians, both covering East African region and include indicative distribution ranges for all species. Where field identification is not certain, voucher specimens (see Karns, 1986) or good quality photographs can be gathered for expert analysis. National, Regional or locality species checklists, where available, are also useful tools for species identification. A pocket size guide is available for identification of venomous snakes of East Africa (Mackay and Mackay, 1985).

- **Sampling methods**
- **Sampling design:**

Stratified random sampling is recommended ensuring inclusion of various habitats within the study area. Permanent sample location e.g. a wetland will be maintained for some amphibians while temporary locations can be applied but within standardized sample frame e.g. forest, woodland, plantation etc.

At least 10 Timed-species Counts will be conducted in each sampling area. Pitfall traps will be placed in at least 1 station per habitat and monitored for 3 consecutive trapping nights. Where applicable, voucher samples will be obtained in multiples (at least 3) to include sexes, life-stage and morphological variations e.g. color phases. For community surveys, at least 30 respondents will be targeted during direct interviews.

The potential causes of bias will depend on the level of training and expertise as the data collected over time by different observers may introduce variability. Time of the day and season of year and prevailing weather conditions could also influence the results. To minimize bias, the expertise and number of observers should be standardized.

- **Monitoring requirements**
- **Personnel**: Coordinator, Herpetologists and technical staff
- Capacity building proposed to be conducted during filed surveys by experienced staff

- **Equipment:** Hoe, snake tongs, snake sticks, 10 L buckets, Trowel, Polythene sheet/barrier, panga, preservative (Formalin 10%), specimen jars, cloth bags, weighing balance, catapults, GPS, wooden stakes, Euthanizing agents (Pentobarbital, MS222), syringes & needles, threads & sewing needles, sex probe, magnifying lens, labels, dissecting kit, stop-watch, measuring tape, camera, veneer/digital calipers and maglites.



Plate ……:A snake handler demonstrating the use of a snake tong and protective goggles against spitting cobra venom.

- **Data recording and storage**

Reptile and amphibian field observation data sheets will be received by the coordinator and NMK Herpetologist for national compilation and analysis. The species observation records database and high-resolution photographs will be stored by the national coordination office. Appropriate records will be integrated into the National Herpetological Repository at NMK.

- **Data analysis**

Data on species records can be expressed as: -

I. **Relative frequency index** can be used to determine which species are most common and the ones that are rare. Number of sightings per hour derived from total time spent searching multiplied by the number of people searching.
II. **Pitfall traps** - will be summarized in terms of trap nights (total number of pitfalls multiplied by the number of nights). Trapping success can be calculated from the number of captures as a percentage of trap nights.
III. **Species richness and abundance** per study site can be shown graphically in to illustrate cumulative number of species (CNS) or cumulative number of individuals (CNI) against the number of days. Further comparison can be made across seasons, sites, elevations and other such variables.
IV. **Species Trends (abundance and richness)** over time e.g. 5 yr. period as data becomes available

Modeling for future scenarios using point data (in collaboration with GIS Unit)

- **Indicators**

I. Trends in species richness
II. Trends in relative abundance index
III. Species ranging patterns (extent and area of occurrence)

- **Reporting**

Annually using technical reports, workshop presentations and publication of scientific papers

- **Institutional collaborations**

WRTI, NMK, KWS, County Governments and relevant stakeholders in conservations areas.

- **Data recording forms**

1. Herpetofauna Time-Limited Search Observation datasheet

Observer:		Habitat type:			Date:		
Transect Name		Start time:			End time:		
Site/Locality		Lat/Long:			Alt:		
Weather Data							
Time/Block	Species	No of individuals	Observation type (direct /indirect)	Life stage e.g. adult, sub-ad, juvenile, tadpole	Sex	Micro habitat found e.g. burrowing, under the rock, log etc, forest canopy, leaf litter	Remarks e.g. other none herp species observed, morpohological notes, behavior etc

Table ……: Herpetofauna Time-Limited Search Observation datasheet

2. Herpetofauna pitfall traps field datasheet

Observer & contacts:		Date:	
Survey Area/Trap station: Trap Checking Time:			
GPS location		Microhabitat (see examples in datasheet 1)	
Vegetation		Topography e.g. Plain Hill, Mountain Plateau, valley	
Leaf-Litter cover		Lunar Phase New moon, Full moon, ½ moon (1st or 3rd Quarter)	Temperature

Trap Line & No (Trap array & Bucket #	Species	# of individuals	Sex	Life Stage e.g. adult, sub-adult, juvenile, tadpole	Remarks e.g. • Other none herp species • Morphological notes • Behavior • etc.

Table……..:Herpetofauna pitfall traps Field Observation datasheet

3. Voucher specimen datasheet

Collector:			Specimen Field#		Data Sheet Ref:
Site:					
GPS location					
Species:			Sex:		Age:
Pregnant:			Breeding Condition		
Colour/Markings:			Endoparasites:	Ectoparasites:	
Measurements:					
HW mm HL mm	TL mm	Snout-Vent mm	LEG mm	Other mm	Weight g
Scale Counts	Mid-Body:		Ventrals:	Labials:	Caudal/Sub-caudals:
Materials Preserved:					
Skin	Skull	Skeleton	Faeces	Blood	Kidneys
Stomach Contents:					
Remarks/Other					

Table……:Voucher Specimen Datasheet [Separate sheet for each sample collected, for standard measurements, see Spawls et. al. (2002) & Channing and Howell (2006)]

- **Monitoring Protocol for Terrestrial and Aquatic Invertebrates**

Invertebrate monitoring is vital for conservation because these organisms are key to ecosystem functioning. They support pollination, decomposition, nutrient cycling, plant reproduction, and food web dynamics and serve as prey for many vertebrates. Monitoring invertebrate populations provides insights into ecosystem health, as they are sensitive to environmental changes such as habitat degradation or climate shifts. Hence their inclusion in assessments ensures a holistic understanding of biodiversity status, enabling the development of strategies that support ecosystem resilience and sustainability.

- **Reasons for monitoring**

I. Invertebrates are highly effective indicators of ecosystem health as they respond sensitively to environmental and human-induced stressors.

II. Monitoring will support the conservation of rare, endemic, threatened and range restricted invertebrate species
III. Invertebrates perform essential ecosystem functions, including pollination, nutrient cycling, and decomposition.
IV. Certain invertebrate life cycles are valuable in wildlife forensics, such as determining time of death of animal carcasses.
V. Invertebrates can be sustainably utilized by local communities to support eco-friendly enterprises and community livelihoods including beekeeping, butterfly and silk farming.

Table …..: Invertebrate taxonomic groups and their utility as indicators of ecosystem health and function

Key invertebrate group	**Change indicated**
Butterflies	Forest disturbance
Dung beetles	Extent of logging and savannah grassland
Ground beetles	Grassland topsoil removal
Tiger beetles	Forest degradation
Longhorned beetles	Forest management
Scolytid beetles	Pollutant effects on forests
Beetles and Grasshoppers	Grassland management
Hemipterans (Bugs)	Grassland habitat disturbance
Bees and beetles	Habitat fragmentation
Bees	Changes in general habitat quality
Dragonflies, stoneflies, mayflies and caddis flies	Water quality and aquatic habitat integrity
Collembolans, beetles and butterflies	Landscape and ecosystem sustainability
Flies, staphylinid beetles, butterflies	General habitat quality

- **Monitoring objectives**

I. To monitor abundance, diversity and distribution of invertebrates in key ecosystems
II. To assess habitat conditions and identify threats to invertebrates' habitats

- **Areas to be monitored**

The following sites will be prioritized: Protected Areas (National parks, reserves, conservancies) Wetlands (Lakes, swamps, rivers etc.).

- **Frequency of surveillance**

Monitoring is recommended to be done annually in both wet and dry seasons for species of special concern while for diversity surveys, every 3-5 years should be considered. For rapid biodiversity assessments, the same protocol can be applied and where time is limited all survey methods that do not involve trapping can be employed.

- **Observation / data types**

I. Invertebrate species checklist
II. Abundance of key invertebrate species.
III. Environmental parameters i.e. temperature, rainfall, humidity, and water quality
IV. Land use type, habitat structure, type and status
V. GPS coordinates to generate distribution maps

- **Survey methods**

1. **Timed Direct Searches (TDS)**

A TDS involves walking along a transect over a fixed time period collecting invertebrates under tree logs, rocks, on vegetation etc., invertebrates sampled include; longhorn beetles, butterflies and scolytid beetles Sometimes it can involve use of aspirator, aerial/sweep net and forceps

2. **Collecting nets:**

Aerial nets - these will be used to collect flying insects like butterflies, flies, dragonflies and bees. The net should be lightweight, made of fine, soft, durable material. White fabric is generally used and the handle can be wooden or aluminum with comfortable grip. Once an insect is observed, a surveyor should position the net properly and strike swiftly to catch the insect then flip the net to prevent the insect from escaping. The specimen can be removed from the net with fingers if harmless, or directed into killing bottle or vial of preservative.

Sweep nets - an effective way of collecting large numbers of specimens, especially many small bugs and beetles, in grass and foliage. The net is swung through the vegetation to dislodge the specimens, which are knocked off plants into the bag of the net. Sweep nets are sturdier than aerial nets, with a wider diameter, and usually have a hexagonal shape which allows better contact with the foliage being swept. Collected specimens can be removed from the net by use of aspirator.

Aquatic nets - these are used for sampling aquatic invertebrates (stoneflies, mayflies, caddis flies etc.) by dragging it through the water body and transferring the caught arthropods into a white tray to facilitate sorting. The net should offer minimum resistance when dragged through water and should be made of a strong transparent synthetic mesh such as nylon.

3. **Traps:**

Pan traps - these are mainly used to collect pollinators such as bees, some species of beetles, flies and also crop pests such as aphids and fruit flies. The traps are usually small bowls painted

with different colors i.e. yellow, blue, pink and white to mimic flowers. The traps are spread randomly across a transect and half filled with water mixed with odorless detergent to break the water surface tension. When monitoring pests, the traps should be set in the crop under investigation. The bowls / traps should be inspected every evening to harvest trapped insects which should be stored in well labeled vials containing 70% ethanol.

Pitfall traps - these are used for trapping flightless ground living arthropods, especially ground beetles, collembolans etc. The trap (usually 125 ml containers) should be placed in a hole with the upper rim flush with the ground surface. A killing agent and preservative, such as ethylene glycol, should be placed in traps to avoid decay of caught specimens. Sometimes, baits can be added in the traps to increase its effectiveness, the type of bait will depend on the specimens one wishes to catch e.g. animal dung when targeting dung beetles.

Butterfly traps - these traps are specifically designed to capture fast-flying butterflies, such as Charaxes spp., that dwell in tree canopies and cannot otherwise be reached. These butterflies are attracted to bait in the trap. A butterfly trap is made from a vertical gauze cylinder, closed at the top, with a landing platform at the bottom. A gap is left between the edge of the cylinder and the platform. The bait is placed in a small bowl positioned in the center of the platform. The trap is hoisted over a high tree branch with a rope, and lowered to remove the catch. Butterfly traps should be monitored regularly as they can fill quickly and specimens will be damaged if they flutter against each other. Effective bait consists of over-ripe bananas, rotten meat or fish and animal dung.

Light traps - this is the most common method for collecting nocturnal specimens that hide or rest during the day in places where they are unlikely to be seen e.g. longhorn beetles, some carabids, moths etc. The simplest light trap consists of suspended white sheet with light hung in front of it to attract/lure specimens. Specimens that settle on the sheet can be collected in killing bottles or with an aspirator. The best time to trap is on a dark night. Light trapping is most unproductive during the phase of full moon. Weather conditions such as wind speed and humidity will also affect the numbers of specimens coming to a trap.

Malaise traps - these traps are mainly used to catch low flying insects e.g. bees, wasps and flies. This type of trap resembles a tent with two open sides. A vertical gauze wall in the middle intercepts flying insects, which are directed upwards into a killing bottle fixed to the highest point of the trap. As insects tend to fly along clearings in the vegetation, like footpaths, the traps should be erected across such a flight path especially where it narrows.

4. **Extractors:**

Berlese (Tullgren) funnels - this is specially designed for extracting invertebrates that live in leaf-litter, humus and soil e.g. ground beetles, collembolans etc.; these species are usually

photophobic preferring moist dark conditions. A sample of leaf litter is placed on a gauze tray in a funnel; a light bulb is positioned above the sample and a bottle of alcohol below the funnel. The bright light and the drying effect of the hot bulb drive the specimens down into the funnel until they fall into the alcohol. Care should be taken not to dry the sample too rapidly as this will kill the slow-moving specimens before they reach the bottom of the funnel.

Winkler selectors - the Winkler selector works on the same principle as the Berlese funnel but are made of canvass and allow the sample to dry out under natural conditions. It is designed to use in the field where there is no electricity.

- **Killing and storage:**

a) Once specimens have been collected, they must be killed and stored until they are mounted and/or preserved permanently. Killing and temporary storage methods vary according to the type of arthropod that has been collected (SOP1).

b) Collected specimens have to be taken through some processing procedures before identification and storage (SOP2).

- **Sampling design**

Stratified random selection will be used where the study area is divided into distinct strata based on characteristics such as topography and vegetation. Sample surveys with one kilometer transect will be employed during the assessments. The number of transects allocated to each stratum should reflect the diversity and extent of features present. Setting up permanent transects will allow for long term monitoring of state and trend of invertebrates, hence the site location must provide a complete representation of all habitat types in an area.

The wet season survey will be undertaken in April/May, while the dry season survey will be conducted in August/September or January/February, depending on site-specific climatic conditions. Daytime surveys will be carried out between 9:00 am and 5:00 pm, and night surveys between 7:00 pm and 10:00 pm.

The number of samples are determined by number of traps and the duration of sampling in a given transect. The following table depicts different methods and standard durations required for sampling.

Method	**Minimum number of transects**	**samples**	**per**	**1km**
Pitfall traps	45 traps for three nights			
Timed direct searches	1 hour per person			
Butterfly traps	15 traps for 2 days			
Pan traps	20 traps for three days			
Light trapping	4 hours			
Litter samples	10 samples			

Aquatic nets	5 points in a 10x10 m2 area			

The survey results can be biased by several factors, including disturbance of traps by humans or animals, inconsistent timing of surveillance, changes in weather conditions and the choice of survey methods. Disturbed traps may lead to partial or complete data loss and should only contribute to species checklists rather than data for comparative analyses between different transects. Sampling must be conducted consistently across transects and localities to ensure comparability, while daily weather conditions should be recorded since invertebrate activity is strongly influenced by temperature and other environmental factors. Survey methods survey methods should be determined by objectives of the survey as different methods target specific invertebrate groups.

- **Indicators**

- Trend in species richness and relative abundance
- Trend in species distribution among different study sites

- **Monitoring requirements**

I. **Personnel:** Trained and experienced Research Scientists, Technicians acquainted with field sampling techniques, preservation and proper identification of invertebrates.

II. **Equipment required:** Map, GPS, Hydro-thermometer, pH meter, portable generator, dissecting kit, killing jars, traps (e.g. pitfall traps, sweep net, pond net etc.), ethanol, field insect boxes, mattock, bucket, sorting tray, data sheets, raincoats, gumboots, detergent, entomological pins, plastic bags/ zip locks, butterfly envelops, specimen vials, field notebook, pencil / rotrin pen, labeling paper, batteries, generator petrol and oil, mercury vapor lamps.

III. Data recording and storage

IV. Record the data collected in the standard invertebrates' data sheets. After field work data verification will be done to check the accuracy of the data entries against the original data sheets.

- **Data analysis**

I. Species cumulative curves - to assess the adequacy of sampling in a given study area.

II. Species richness and evenness - multivariate indices - Shannon-Wiener index, Margalef's diversity index (d), Pielou's evenness index (J')

III. Analysis of Variance (ANOVA) - to test the significance between sampling in different seasons and habitats.

- **Reporting**

Field technical reports, workshop presentations and publication of scientific papers. Publications in websites to disseminate the findings and increase public awareness.

- **Institutional collaborations**

I. Wildlife Research and Training Institute
II. National museums of Kenya
III. Kenya Wildlife Service
IV. Conservancies
V. Conservation NGOs and community groups
VI. County Governments

- **Invertebrate Data recording forms**
- **Invertebrates Survey field data sheet**

Survey tittle:_____

County:_____Locality:_____

Transect Number:_____Point number:_____

Date:_____Time:_____Temperature:_____Humidity:_____

GPS Coordinates: N_____E_____Alt._____

Collectors/Observers Name:_____Precipitation:_____

Host plant:_____(E.g. *Acacia* tree leaves, *Lantana camara* flowers etc.)

Habitat type/Status: _____ (Examples of type; grasslands, shrubland, indigenous forest, pond etc, Example of status; logging, overgrazed, intact forest etc.)

Method of collection:_____(E.g. Pitfall traps, hand picking, baited traps etc.)

Season: _____(E.g. Wet or dry)

No.	**Order**	**Family**	**Morpho species**	**No. of individuals**	**Photo no.**

Table……: Field Data Recording Sheet for Invertebrates Survey

Laboratory Recording Data sheet for Invertebrates											
Accession #	Order	Family	Genus	Species	Author	Locality	GPS Coordinates	Date of Collection	Collector	No. of individuals	Photo no.

Table……: Invertebrates laboratory recording data sheet

- **Standard Operating Procedures (SOP)**
- **SOP1: Killing and temporary storage**

- **Killing methods**

1. **Pinching**

This is appropriate for killing butterflies and moths. The thorax is usually pressed gently with fingers then the specimen is stored in a butterfly envelop. Label the envelope with the necessary field data.



Plate ……..: pinching thorax of butterfly



Plate ……..:butterfly envelop

2. **Use of ethyl acetate**

Most of specimens collected using sweep-nets, light traps and beating sheets are killed by putting them in a bottle containing few drops of ethyl acetate. The bottle should be wide mouthed and made of glass, polypropylene or polyethylene (ethyl acetate dissolves many other plastics). Care should be taken to avoid inhaling fumes in the killing bottle. Absorbent paper should be placed inside the bottle to soak up condensation, regurgitated or defecated liquid.

3. **Use of liquids**

All soft bodied invertebrates including larval stages and specimens collected using pitfall traps and aquatic nets are killed in 70% ethanol. Insect larvae should be immersed in near boiling water to avoid loss of original color before transferring into 70% ethanol.

- **Temporary storage of specimens**
- **Temporary storage of dry specimens**

Butterflies and other large winged insects can be stored in folded protective waxpaper envelops. Most arthropods can be conveniently stored between layers of absorbed papers, which are properly arranged in wooden insect boxes. A fungicide e.g. phenol or dettol should be added to

the container if the specimens have not dried completely. Insect repellant such as naphthalene should be added to prevent attack by pests such as ant and museum beetles.

- **Temporary storage of specimens in liquid**

Specimens collected using pan traps, pitfall traps and aquatic nets are temporarily stored in 70% ethanol as they await sorting and permanent preservation and storage.

- **SOP2: Laboratory processing, preservation, labeling and storage**
- **Cleaning samples for preservation and identification**

Some specimens may require cleaning especially those collected using pitfall traps and aquatic nets. Particular care should be taken to ensure that samples are being processed thoroughly and efficiently. The purpose of sorting is to remove invertebrates from other material in the sample.

- **Procedure:**

I. Sample processing begins by pouring the sample into a sieve with micro-pores (500-µm) placed in a catch pan.
II. Rinse the sample contents in the sieve with tap water to flush the residual preservative. Large organic material (>2 cm) should be removed by hand and rinsed into the sieve. Each piece of debris removed from the bulk sample should be carefully inspected to ensure that all attached organisms are removed. The rinsed organic material should then be kept separate from the rest of the sample or placed in the original sample container along with the original preservative.
III. Inspect the sieve to ensure no invertebrates remain following rinsing. If present, remove any specimens and add them to the organic sample fraction.
IV. The sieve should then be placed in a shallow pan of water, and the contents floated until they are evenly distributed on the pan bottom. The sieve should then be carefully lifted from the water so that contents are not redistributed. The separated sample is now ready for sorting.

- **Preservation methods**
- **Dry preservation**

Invertebrates that are to be preserved dry are best mounted in ways that facilitate study and permanent storage. Specimens should be mounted soon after killing. Non-mounted specimens that have been temporarily stored dry can be relaxed to make it flexible enough for pinning. Insects longer than 8 mm are usually mounted on pins pushed through the thorax (Figure 4), insects that are too small for mounting directly on standard pins are double mounted on card points, card platforms (Figure 5), minute pins (Figure 6) or gelatin capsules (Figure 7).

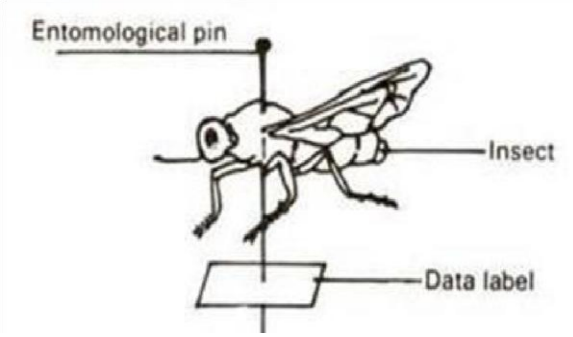


Figure ……:Direct pinning

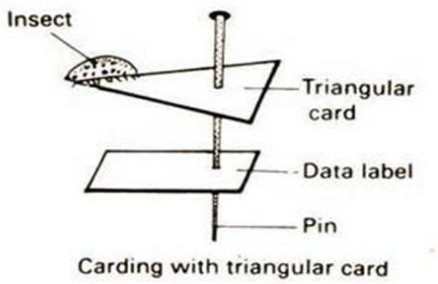


Figure ……:Direct pinning

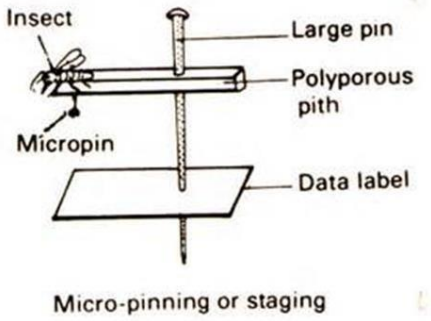


Figure ……:Gelaltin Capsules

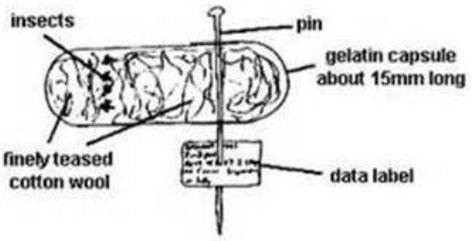


Figure ……..:Micro pinning

- **Wet preservation**

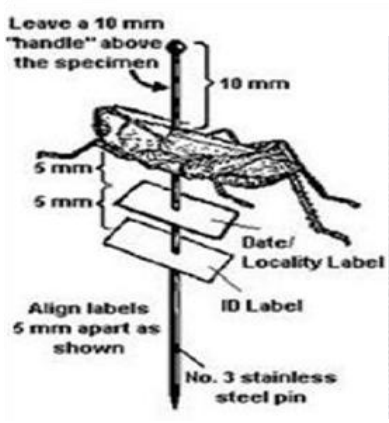
Most soft-bodied invertebrates become much distorted when they dry out as do eggs and immature stages. They have to be stored permanently in suitable liquid preservative. Ethanol (70-95%) is generally used.

- **Labeling**

Invertebrates that are collected for ecological, taxonomic, physiological or any other study must always be labeled. The correct labeling of specimens cannot be overemphasized. Specimens without label are of no scientific value, while incorrect information on labels can lead to misinterpretation of results, often with serious consequences. Data captured include; Locality, Date of collection (e.g. 31.vii.2013), GPS coordinates, Collector, Method of collection, Host plant.

- **Labeling pinned specimens**

Good quality thin cards are suitable for label in pinned specimens (Figure 8). Labels should be small and neat. Never include data on the underside of a label, the information will be overlooked. A pinning block is used for spacing labels neatly on the pin (Figure ….).



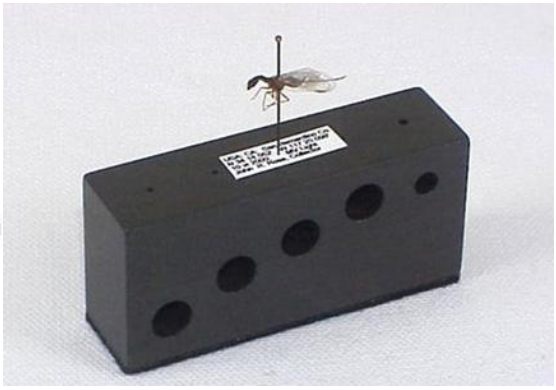


Figure specimen……. Labeling pinned Plate ……:Pinning block

- **Labeling wet preserved specimens**

Label for materials preserved in liquid should be hand written in pencil or Indian ink or printed with alcohol proof print on acid free paper. Preferably only one label reflecting all the data should be used. A label stiff card should be cut to fit snugly inside the vial so that it does not move around and damage the contents and positioned with the printed side facing outwards so that it can be read through the glass.

- **Permanent storage**
- **Dry collections**

These mostly comprise the pinned specimens that are stored in glass-topped drawers (Figure ……) slotting into special wooden or steel cabinets (Figure …..). The drawers have tight-fitting lids to keep out museum pests, dust and moisture.



Plate….: Insect drawer

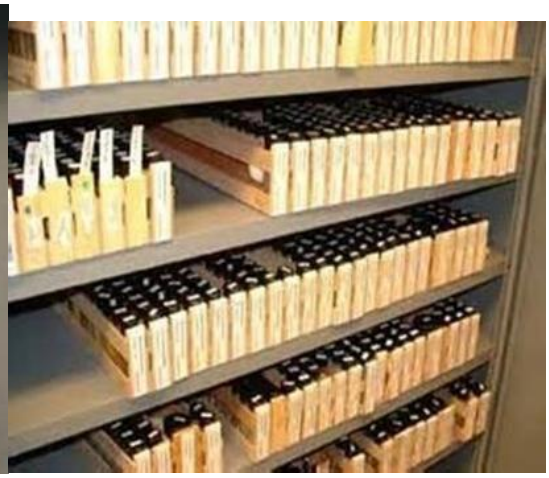


Plate….: Insect Cabinets

- **Wet collections**

These are mostly collection of specimens stored in ethanol in glass vials with tight -fitting stoppers. Ideally the vials should be of uniform size, and are best stored upright in single rows in specially made racks (Figure….). These racks are stored in shelves in cabinets. Honey jars are also convenient containers for preserving specimens in liquid.





Plate…….:Specimen vial *Plate ……..:Racks for wet collections*

- **HYDROLOGICAL MONITORING**

Hydrological monitoring is the systematic observation and measurement of water-related parameters in the environment, such as rainfall, river flow, groundwater levels, and water quality. Surface water quality and quantity monitoring will be undertaken in key ecosystems such as wetlands and river systems. This protocol provides guidance for monitoring the physical, chemical, and biological parameters of water to ensure suitability for the environment, wildlife and human use.

- **Reasons for monitoring**

1. Wetlands are critical ecosystems supporting diverse species including migratory species and serve as breeding and nursery grounds for birds and fish, thus wetland health influence distant ecosystems.
2. Monitoring shows whether restoration activities are achieving targets and guides adaptive management
3. Monitoring water quantity and quality provide information on habitat suitability for plants, fish, and wildlife.
4. Monitoring water quantity and quality in wetlands and river systems provides calibration and validation data for models, enhancing prediction reliability and supporting sound water resource management decisions.

Aim: To understand long-term changes in wetlands health and functions to guide in adaptive management as part of a strategy to conserve these important ecosystems.

- **Monitoring objectives**

I. To assess physical-chemical and biological conditions of wetlands over time
II. Provide baseline data and long-term trends for management and restoration decisions
III. To detect pollution and contaminants in water to guide management actions
IV. To support compliance with environmental regulations and conservation goals
V. To assess water quantity over time to guide in planning and water allocation for various uses and ensure adequate environmental flows are maintained

- **Areas to be monitored**

The monitoring will target the key water bodies and wetlands in Kenya's Protected Areas and the major river basins. More focus will be given to wetlands of international importance particularly sites listed as Ramsar sites, World heritage sites and Key Biodiversity Areas. The target sites include: Lakes Nakuru, Elementaita, Bogoria, Magadi, Naivasha, Ol-Bolossat, Jipe, Victoria and Turkana; Rivers Tana, Athi, Mara, Ewaso Nyiro , Nzoia, and Sabaki rivers as well as the coastal wetlands.

- **Frequency of monitoring**

Water quality and quantity monitoring for surface water will be conducted on a monthly basis in selected sites such as the Ramsar sites and the rift valley lakes due to their significance in hosting threatened water birds. The other wetlands and river systems can be monitored on a quarterly basis or twice a year depending on availability of resources. Water quality parameters such as dissolved oxygen, electrical conductivity, pH, temperature, nutrients, turbidity, chlorophyll a & b, will be collected monthly in the selected sites. Parameters such as heavy metals, agrochemicals, sediments, phyto-planktons and zoo-planktons and biological samples can be sampled annually.

- **Survey methods**

I. In-situ measurements; water physical chemical parameters like pH, temperature and DO will be measured in-situ using water quality meters and or by use of automated sensors for continuous monitoring
II. Grab and composite sampling: will be used for sample collection for laboratory analysis
III. Water Level (Stage): measured using staff gauges or automated sensors in key rivers
IV. Stream flow/discharge measurements; use of flow meters or acoustic Doppler current profilers (ADCPs)
V. Innovative technologies e.g. use of automated sensors, data loggers, remote sensing for real-time monitoring and eDNA technology in water quality and quantity monitoring will be promoted

Standardized methods for water sampling, preservation, and analysis will be adopted (APHA, 2023)

- **Sampling design:**

Permanent sampling points will be established on the key water bodies although this points can be varied depending on shoreline changes. Permanent sampling sites will be stratified to account for land use activities, where the rivers enter and leave protected areas as well as permanent water bodies in protected areas. For rivers, sampling points will be established downstream, midstream and in the catchment where possible. For those flowing through protected areas, sampling points should also be established depending on potential sources of nutrient loads with respect to land uses, as well as the water flow in and out of protected areas. Lakes, dams, swamps and water pans should be sampled at the inlet and outlet points and at the centre and at key wildlife drinking points.

Potential bias can be caused by poor handling of samples during collection, storage and processing and delay in analysis resulting in changes in water parameters. Lack of calibration of Sampling under different environmental conditions can also lead to bias in data is used for comparisons.

- **Monitoring requirements**

Personnel responsible: Research Scientist, Research Assistant experienced in aquatic sample collection and storage, laboratory technician for sample analysis, coxswain and divers for deeper water bodies. Training will be required for field staff to ensure standardization of water and sediment sampling techniques.

- **Equipment required**

Multi-parameter water quality meters (pH, temperature, dissolved Oxygen conductivity), turbidity meter, automatic samplers, sample bottles, grab samplers, Secchi disk, cool box, preservation agents, filtration units, gloves, calibration solutions, batteries, labels, Acoustic Doppler Current Profiler (ADCP), flow meters, staff gauge plates, stopwatch, GPS, waders, accredited lab facilities, boats, safety gear. eDNA samplers and automated water monitoring sensors (IOT sensors) and data loggers for real-time water monitoring. Note: Ensure recalibration of water monitoring equipment for accurate and comparable results before each sampling.

- **Data recording and storage**

Data will be filled in data forms and after verification entered into the database at the research Center. Centralized database or cloud-based platforms will be established for automated water monitoring systems.

- **Data analysis**

Trends in water quality and quantity will be analyzed and compared with water quality guidelines and standards for example WHO drinking water and environment discharge guidelines. Water quality indices will also be derived to help track improvement or deterioration in water quality over time and space. Water quantity analysis will guide in determining water allocations for multiple water uses in key wetlands while ensuring adequate environmental flows are maintained.

- **Reporting procedures**

Technical reports will be prepared after every field sampling and key findings presented in scientific conferences and published in scientific papers.

- **Indicators**

I. Trends in physical-chemical levels temperature, turbidity, pH, DO, EC, nutrients
II. Trends in river flows over time
III. Level of pollutants - heavy metals, pesticides

- **Institutional collaborations**

WRTI, Water Resource Authority (WRA), WRUAs, NEMA, KWS, Meteorology department, Ministry of Environment.

- **Data recording forms**

1. **Water quality sampling data sheet: lakes, rivers, streams, dams, pans**

River/lake name:		**Site name:**	
Date:		**Time:**	
Weather now: (clear, partly cloudy, cloudy, overcast, stormy, rainy, drizzle)		**Weather in past 24 hours:**	
GPS coordinates:		**Sampling personnel:**	
Parameter/Test	**Unit**	**Results**	**Comments**
Sampling depth	Cm		
Secchi depth (SD)	Cm		
Total depth	M		
Water colour			
Flow rate	M3/S		
Air temperature	^{0}C		
Water temperature	^{0}C		
pH	pH Scale		
Dissolved oxygen	(‰)		
Dissolved oxygen	Mg/l		
Conductivity	µS/cm		
Turbidity (TD)	NTU		

Salinity	Mg/l,		
TSS	Mg/l		
Total Nitrogen	Mg/l		
Nitrates	Mg/l		
Ammonia	Mg/l		
Phosphates	Mg/l		
Orthophosphates	Mg/l		
Spirulina	Cells/ml		
Chlorophyll (a,b,c)	µg/ml		
Flouride	Mg/l		
Biological (Total coliforms, *E. coli)*	CFU/100ml		
Heavy metals (Pb, Cd etc.)	Mg/l		

2. Water discharge/ quantity sampling datasheet

River name:					**Site/station name:**		
Date:					**Time:**		
GPS coordinates:					**Recorder:**		
Method 1: Gauge stations readings							
GHT 1 (9.00 am)					GHT 2 (4.00 pm)		
Method 2: Acoustic Doppler Current Profiler (ADCP)							
Devise used: Start time: End time:……..							
Left bank: Sloping, vertical other					Right Bank: Sloping, Vertical, Other		
Transect	Bank	Distance	Depth (m)	Velocity (m/s)	Cross-sectional Area (m2)	Discharge (m3/s)	Remarks

- **Monitoring Protocol for Fresh Water Fish Species**
- **Introduction**

Freshwater fish are fish species that spend some or all of their lives in fresh water bodies such as rivers, lakes, ponds and inland wetlands. They are adapted to survive in environments with varying oxygen levels, temperature, and water flow.

Freshwater fish are an essential part of aquatic ecosystems, playing key roles in food webs, nutrient cycling, food security and as environmental indicators.

The growing exploitation fisheries resource requires accurate information and continuous resource monitoring. Fisheries monitoring is crucial for evaluating both current fish stocks and long-term yield potential as well as environmental factors, making it an integral part of sustainable fisheries management.

- **Reasons for Monitoring:**

Monitoring of fresh water fisheries supports effective resource management by:

I. Enhancing biodiversity conservation through tracking distribution and diversity of endangered aquatic fisheries
II. Helps in detecting environmental changes and impacts of disturbance and human activities and climate on aquatic resources
III. Understanding resource use patterns over time and provide data for regulations and sustainable management
IV. Supporting fisheries development and identification of potential areas for fishing or aquaculture.

- **Monitoring objectives**

I. Assess fish species abundance, diversity, distribution and biomass trends over time
II. Establish baseline and monitor status of endangered and threatened fish species
III. Understand impacts of environmental change on freshwater fisheries
IV. Track the spread and impacts of non-native fish species

- **Areas to be monitored in the inland fisheries**

The key areas targeted for fish monitoring include major lakes and important rivers particularly those in protected areas such as; Lakes Nakuru, Baringo and Jipe and Mara river basin. Within the lakes monitoring will focus on; fish breeding sites, landing beaches, estuaries and riparian areas.

- **Types of data to be collected**

Fisheries surveys will collect information; fish stock assessments, fishing effort data, biological data, environmental data (temperature, DO, Salinity), aquatic vegetation, macro-invertebrates and socio-economic data.

- **Data Collection Methods**
- **Fish Stock Assessments**

Fish stock assessment is the process of estimating the abundance, growth, mortality, and recruitment of fish populations. It entails the collection and analysis of demographic information to determine changes in the abundance of fishery stocks and predict future trends. Fish stock assessment help fishery managers to determine the fisheries population health to guide decisions

on fishing regulations and ensure the long-term sustainability of fishery populations and the fishing industry.

- **Methods:**

I. Hydro-acoustics and trawl surveys,
II. catch assessment and frame surveys,
III. Biological - age, size, growth rates, mortality
IV. Environmental assessments
V. eDNA analysis

1. Hydroacoustic surveys

Hydroacoustic uses active sonar to study fish by sending sound waves through water and analyzing the reflected signals. Traditionally, hydroacoustic assessments are conducted from moving boats to estimate fish biomass and map their spatial distribution. Unlike older methods such as net trawls, diver surveys, hook and line, or video, fisheries acoustics relies on the physics of sound transmission in water to detect and quantify organisms in the water column. By measuring the travel time and strength of sound echoes, scientists can determine fish location, size, and estimate biomass. Hydroacoustics is an efficient, non-invasive technique that provides high-resolution data in space and time making it a practical alternative for monitoring especially in protected areas where fishing gear is restricted.

Types of data collected:

I. Fish location and water depth
II. **Fish abundance,** distribution, **density and biomass**
III. Fish characteristics - size, shape, and spacing

Limitations: hydro-acoustics cannot identify distinct species and can be less accurate in shallow areas or near riverbeds, can produce variable results depending on the vessel used, and is expensive. Therefore, for ground thruthing, use bottom net hauls to collect fish samples and estimate catch rates from surveyed areas

2. Trawl surveys

Trawl fish surveys are scientific studies that use nets dragged behind research vessels to sample fish and other marine organisms, either from the seafloor (bottom trawl) or midwater (pelagic trawl). They can cover large areas and yield detailed biological information, hence it is a key tool in sustainable fisheries management and marine biodiversity monitoring.

Data collected: Species composition, abundance, size, and biomass, helping researchers monitor fish populations, assess stock health, and detect changes in marine ecosystems over time.

Limitation: Their effectiveness can be limited by net efficiency, environmental conditions, and their potential impact on the seafloor.

3. Fish landing data

Fish landing data such as species type, weight, and value is collected daily by Beach Management Units (BMUs) under the Kenya Fisheries Service (KeFS). The data is collected daily and submitted monthly to KeFS. Data collection occurs mainly in the morning hours between 6-11am at landing sites.

4. Fishing effort data

Fishing effort data quantifies the intensity of fishing activity such as; fishing trips, area, hours and gear used over time indicating fishing pressure. It helps in managing fish stocks and guide fishery management decisions.

5. Environmental data

Assessment of water and general aquatic environmental conditions such as pH, DO, salinity, chlorophyll, turbidity and nutrients will be conducted following standard methods (APHA, 2012) and comparing with sensor logged values where available.

- **Monitoring requirements**

Personnel: Research Scientist (fisheries), Research assistant, coxswain, laboratory technicial

Equipment; hydroacoustic, electrofisher, fishing nets (trawl nets, seine nets, gill nets), plankton nets, weighing scales, tape measure, water quality meter, sample bottles, Secchi disk, cool box, GPS, gloves, waders, boats, data sheets, pens, calculators, tape measures, and computer applications for data management. Lab facilities.

- **Indicators**

I. Trends in fish species richness and biomass
II. Trends in fish stocks and fish landing data
III. Long-term shifts in fish communities

- **Institutional collaborations**

WRTI, Kenya Marine and Fisheries Research Institute (KMFRI), Kenya Fisheries Service (KeFS), BMUs, NMK, Water Resource Authority (WRA), WRUAs, KWS, County Governments.

- **Freshwater monitoring fish data recording forms**

1. Fish data collection form (stream fishes)

River/lake name:	**Site (Upstream, Downstream):**
Date:	**Time:**

GPS coordinates:		**Recorder:**	
Weather (clear, partly cloudy, cloudy, overcast, stormy, rainy, drizzle):			
Water quality	**Unit**	**Results**	**Comment**
Water temperature	^{0}C		
Dissolved oxygen	(%)		
Dissolved oxygen	Mg/l		
pH	pH Scale		
Conductivity	µS/cm		
Turbidity (TD)	NTU		
Nutrients	Mg/l		
Fish data			
Gear type & number	**Species**	**Length of fish**	**Comment**

2. **Fish Landing data sheet**

- **Monthly statistics data sheet**

Name of Beach (Landing Site) ……

Fish Production for the Month of ……..

	Species	**Weight (in Kgs)**	**Value (Ksh)**
	Critically endangered		
1	*Oreochromis esculentus (*Singidia tilapia)		
2	*Oreochromis hunter (*Lake chala tilapia)		
3	*Oreochromis jipe (*Jipe tilapia)		
4	*Oreochromis variabilis (*Victoria tilapia)		
5	*Ptyochromis sp. nov. (*Rainbow sheller)		
6	*Xenoclarias eupogon (*Lake victoria deepwater catfish)		
	Endangered		
7	*Alcolapia alcalicus (*Magadi tilapia)		
8	*Marcusenius victoria (*Victoria stonebasher)		
9	*Xystichromis nuchisquamulatus (*Kyoga flameback)		

10	*Nothobranchius bojiensis* (Plain Northobranch)		

- **Monitoring Protocol for Weather**
- **Reasons for Monitoring**

Weather and climate are strong drivers of ecological dynamics, influencing plant and animal distributions, community interactions, and overall ecosystem states. Understanding prevailing local climatic conditions is essential for interpreting ecological trends, guiding conservation policy, supporting wildlife census operations, informing resource management, and enhancing visitor experience.

Precipitation, temperature, humidity, and other atmospheric variables determine vegetation development, water availability, phenology, and the functioning of entire food webs. Ecosystem classifications used in conservation planning largely depend on climatic variables; therefore, continuous, reliable, and spatially representative weather data is indispensable.
To improve accuracy and reduce labour demands, weather information will now be collected primarily through Automated Weather Stations (AWS) and IoT-connected microclimate sensors, which measure and transmit data electronically in real time. Manual recording will only serve as backup in case of system failure.

- **Conservation Objectives**

I. To guide scientists and conservation managers to make informed decisions on conservation policies, resource allocations (e.g., water points, fire management), and infrastructure development.
II. To understand spatial and temporal distribution of climatic resources available for wildlife utilization.
III. To build climate–ecosystem datasets that improve prediction of droughts, floods, and other environmental extremes.
IV. To provide continuous climate data to support long-term ecological monitoring, wildlife census interpretation, and adaptive ecosystem management.

- **Populations / Areas to Be Monitored**

All national parks, national reserves, conservancies, sanctuaries, and important wildlife conservation areas. Each ecosystem shall maintain at least one AWS, supplemented where necessary by IoT sensors and remote satellite observations.

- **Frequency of Data Collection**

Weather conditions change continuously; therefore:

I. Automated Weather Stations will record data at intervals of 1–15 minutes, depending on configuration.
II. All data will be automatically transmitted to WRTI's central climate database via GSM, satellite, or LoRaWAN.
III. Daily summaries will be generated automatically at 09:00 AM for standardization and compatibility with historical datasets.

IV. During extreme events (El Niño, La Niña, heat waves, storms), the system will issue automated alerts to relevant WRTI staff.

This approach increases accuracy, eliminates manual errors, and ensures round-the-clock monitoring.

- **Monitoring Methods**

I. Automated Weather Stations (AWS) equipped with sensors for rainfall, wind, temperature, humidity, solar radiation, and barometric pressure.
II. Remote-sensed data including satellite-based rainfall estimates (e.g., CHIRPS, GPM), land surface temperature (MODIS, Sentinel-3), cloud cover (Sentinel-2), and vegetation condition (NDVI).
III. IoT microclimate sensors where finer spatial resolution is needed
IV. Drone-assisted microclimate mapping, where feasible, to capture temperature, humidity, and thermal anomalies.

- **Observation / Data Types**

AWS and remote sensing systems will collect the following parameters automatically:

I. Rainfall
II. Air temperature
III. Relative humidity
IV. Solar radiation
V. Soil temperature
VI. Atmospheric pressure
VII. Wind speed and direction
VIII. Visibility (sensor or remote-sensed proxy)

- **Complete Census or Sample Survey**

This remains a sample survey, as each weather station represents one point within a selected habitat or ecological zone. Automatic sensors increase frequency and reliability but do not alter the sampling design.

- **Survey Method**

Weather stations will be **strategically sited**, not randomly placed. Selection is based on:

I. Habitat variability
II. Elevation
III. Representativeness
IV. Accessibility for maintenance
V. Absence of obstructions affecting sensor accuracy

IoT micro-sensors may be deployed in additional micro-habitats to provide finer climatic gradients where needed.

- **Timing of Surveillance / Observations**

I. AWS collect data continuously throughout the day and night.

II. The system will automatically generate a standardized daily dataset at 09:00 AM, aligning with global meteorological practice and historical KWS protocols.
III. Manual observation will occur during calibration or in cases of system malfunction.

- **Potential Causes of Bias and Rules for Standardization**

Automated systems significantly reduce observer bias. Remaining potential sources of bias include:

I. Poor sensor placement (near obstructions, heat sources, reflective surfaces)
II. Inadequate calibration
III. Power interruptions or transmission failures

- **Standardization Rules:**

I. Maintain recommended measurement heights (as per WMO standards).
II. Inspect and calibrate AWS quarterly.
III. Maintain vegetation clearance around sensors.
IV. Cross-check AWS readings with satellite datasets to detect anomalies.

- **Sampling Methodology**

This protocol monitors weather parameters using **permanent, automated sample stations** within selected habitats.
Where AWS are not available, traditional instruments (rain gauges, thermometers) may be used as backups. In remote sites, satellite-based rainfall and temperature data will supplement absent field sensors.
IoT devices provide an affordable solution for extending coverage in rugged, high-biodiversity or risk-prone zones.

- **Temporary or Permanent Sample Location**

Permanent AWS installations are required for robust long-term datasets.
Sensor placement follows international exposure guidelines:

Weather Parameter	Measurement Height	Exposure Considerations
Wind	3 m (recommended) or 10 m (WMO)	≥10 × height of nearest obstruction
Temperature & Humidity	1.25–2.0 m	Shielded in Stevenson screen or radiation shield
Solar Radiation	Consistent height, ≤3 m for maintenance	No obstructions blocking sky view
Precipitation	1.0 m	Shield free of splash-in, drifting, and obstructions
Soil Temperature	5 cm–100 cm depths	Flat, representative surface

- **Method of Sampling Unit Location**

The ecosystem is delineated into habitat types (forest, grassland, riverine, montane). One AWS will be installed in each habitat type to ensure climatic representativeness.

- **Number of Samples**

Equal to the number of weather parameters measured by each AWS (typically 8–12 variables).

- **Monitoring Requirements**
- **Personnel Responsible**

I. Site scientists/technicians
II. Rangers and wardens trained in AWS maintenance
III. ICT support for data transmission and dashboard management

- **Experience and Training**
- **Personnel require:**

I. Basic AWS and IoT maintenance training
II. Calibration procedures
III. Data interpretation skills
IV. Understanding of remote sensing products

- **Materials and Instrumentation**
- **Modern AWS include**:

I. Thermometer
II. Barometer
III. Hygrometer
IV. Anemometer
V. Rain gauge (tipping bucket)
VI. Soil temperature probes
VII. Solar radiation sensors
VIII. Sky camera (optional)
IX. GSM/LoRaWAN communication module
X. Solar panel + battery

- **Advanced optional sensors:**

I. UV index
II. Leaf wetness
III. Soil moisture
IV. Water temperature (for wetlands)

- **Data Recording and Storage**

- **Data will now be:**

I. Recorded automatically by AWS and IoT devices
II. Transmitted electronically to the WRTI central climate database
III. Backed up on cloud servers
IV. Stored in the WRTI Biodiversity Database for integration with ecological data
V. Automatically exported into seasonal and annual reports

Manual datasheets are kept only for redundancy.

- **Data Analysis**

Automatic data processing will generate:

I. Weather charts
II. Seasonal patterns
III. Rainfall distribution maps
IV. Heat stress indices
V. Fire danger rating inputs
VI. Long-term climate trends

AWS data will be cross-verified periodically with satellite datasets.

- **Reporting Procedures**

Each conservation area shall submit:

I. Monthly summaries from AWS dashboard
II. Quarterly climate trend reports
III. Seasonal weather summaries
IV. Annual climate reports integrated with ecological monitoring outputs

Automated alerts (SMS/email) will support rapid response during extreme events.

- **Expected Indicators**

I. Trends in rainfall distribution across habitats
II. Trends in temperature variation
III. Patterns in wind speed and direction
IV. Changes in humidity and solar radiation
V. Predictive relationships between climate and biodiversity responses

- **Institutional Collaboration**

Collaboration with:

I. Kenya Meteorological Department
II. KFS, KEFRI, and Department of Agriculture
III. DRSRS
IV. Academic institutions
V. Lodges and tourism facilities
VI. International satellite data providers (NASA, ESA etc)

WEATHER FORMS

(Automatically logged and transmitted from each AWS)

Parameter	Unit	Frequency	Sensor/Source	Notes
Rainfall	mm	1–5 min	Tipping bucket AWS	Auto-logged
Temperature	°C	1–5 min	Digital thermistor	Min/Max auto-calculated
Humidity	%	1–5 min	Hygrometer	Used for fire index
Wind Speed	m/s	1–5 min	Ultrasonic anemometer	High accuracy
Wind Direction	Degrees	1–5 min	Wind vane/ultrasonic	Auto-orientation
Solar Radiation	W/m²	5 min	Pyranometer	For vegetation modelling
Barometric Pressure	hPa	5 min	Digital barometer	Storm prediction
Soil Temp	°C	Hourly	Soil probe	Multi-depth
Cloud Cover	%	30–60 min	Satellite or sky camera	AI interpreted
Data Transmission Status	-	Real-time	GSM/LoRa/Satellite	Connectivity indicator

- **Monitoring protocol for Marine Wildlife Conservation areas**
- **Introduction**
- **Background Information**

Kenya's coastline extends about 536 km along the seafront, from Vanga in the south (Longitude 4º, 40′ S) and Ishakani in the north (Longitude 1º 41′ S) (Figure xxx). It constitutes critical coastal and marine habitats with diverse and unique biodiversity namely, mangrove forests, seagrass beds and coral reefs, which are interspersed by extensive sandy beaches, bottom sand flats and estuarine

systems as well as terrestrial coastal forests. These ecosystems provide essential ecological services, support production, and serves as the source of livelihoods and income-opportunities for coastal and inland populations.

Coral reef ecosystems: The distribution of coral reefs along the coastline is influenced by oceanographic setting and hydrology (Kenya coast report 2011). Being part of the northern end of the East African fringing reef system, the cover, size, and diversity of coral reef ecosystems decreases northwards along the Kenya coast, due to increasingly poor conditions for reef development, especially the inflows from Kenya's two largest rivers, the Athi and Tana, which suppresses the development of coral reefs between Malindi and Lamu. The patterns of species abundance and diversity are not always clear, reflecting multiple factors and levels of influence, from the regional influence of the Somali current, through the sub-regional influence of river discharge to the local influence of species interactions, habitat, and human intervention (Obura et al. 2000).

Seagrass ecosystems: Seagrasses are submerged marine flowering plants that grow in nearshore environments occurring from the upper estuarine to marine environments (Green and Short, 2003). Seagrass beds are among the most widespread and productive coastal ecosystem types that occur either as monospecific or mixed stands and as such support ecosystem services including fisheries production and nutrient filtering (Constanza et al., 1997).

There are 12 species of seagrass that have been documented to occur along the Kenyan coastline and are widely distributed along the Kenyan coast with most of them occurring as mixed species meadows thus forming complex habitats that host a wealth of biodiversity (Isaac and Isaac, 1968; Ochieng & Erftemeijer 2003). These species include *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides, Halodule minor, Halophila ovalis, Halophila stipulacea, Halodule uninervis, Halodule wrightii, Syringodium isoetifolium, Thalassodendron cilatum, Thalassia hemprichii,* and *Zostera capensis* with *Thalassodendron ciliatum* as the dominant seagrass species (Ochieng and Erftemeijer, 2003). *Zostera capensis* is a rare species in these ecosystems and is categorized as vulnerable in the IUCN red list hence the need to conserve it. Seagrasses normally have a defined zonation pattern from shallow areas to deeper sediments. *Thalassodendron ciliatum* and *Enhalus acoroides* for instance grow in deeper sediments and are considered ase climax species. *Halodule uninervis* and *Halophila ovalis* are transitory species considered pioneer species growing rapidly and surviving well in unstable or depositional environments. *Cymodocea serrulata* occurs normally in deeper sediments.*Marine megafauna:* The Kenyan waters, owing to the rich and diverse ecosystems, hosts more than 35 species of marine mammals including dugongs (*Dugon dugong*), humpback whales (*Megaptera novaeangliae*) and dolphins (*Tursiops spp*). In addition, all the five species of sea turtles and several species of sharks also occur in Kenyan waters. Dugongs and sea turtles have been designated as endangered or threatened and their populations are facing a decline

Status and threats: In Kenya, changes in reef ecology and fisheries have been associated with wide-scale coral mortality or changes in trends of long-term resource use (McClanahan et al., 1999; McClanahan et al., 2001). Of these two, field studies in Kenya have found climate change to

represent the greatest challenge as the effects are broad scale and not easily alleviated by local actions (McClanahan et al., 2005). It is, therefore, important for modern research work to identify resilient coral reefs that can persist through ENSO events as well as anthropogenic factors that reduce the resilience of these thermal tolerant coral reef ecosystems.

Seagrass ecosystems are susceptible to persistent threats that affect their functional stability and continued provision of ecosystem goods and services (Short and Wyllie-Echeverria, 1996). Seagrass loss in Kenya has been experienced in several areas along the coast due to population explosions of sea urchins. Several studies suggest that this phenomenon is substantial and episodic, triggered by overfishing of predators and eutrophication (Eklöf et al., 2008; Daudi 2010). Other anthropogenic threats experienced include shoreline modification, destruction by boat anchors, destructive fishing methods, dredging, oil pollution, and increased land runoff.

Monitoring efforts: Ecological monitoring of the environment is an important component of management, to provide up to date information on which to base decisions and interventions. Kenya Wildlife Service has for many years been building up the capacity of marine rangers to conduct underwater coral reef monitoring. The current monitoring program was initiated in 2004. Other organizations have actively participated in coral reef monitoring. These include KMFRI, WWF, WCS and CORDIO. The data has been collected based on internationally recommended monitoring protocol (GCRMN English et al., 1996) and consistent with established monitoring programs in East Africa. The monitoring methods include line intercept transects for benthic cover and corals, Fish and invertebrates transects and site or threats assessment.

The efforts have however been impeded by a lack of of a functional database framework. This database is important for the long term Marine Protected Areas ecological monitoring. In addition to the database, the monitoring of deeper coral reefs, selecting representative monitoring sites and the Integration of ecological monitoring programs in MPA management plans are key towards ensuring a sustainable and adaptive ecosystem management approaches in a wider seascape.

Global seagrass monitoring efforts started in 1999 when Seagrass-Watch, a global long-term monitoring tool started with currently more than 26 countries participating in the program globally at more than 335 sentinel sites (McKenzie et al., 2003). In 2001, the Global Seagrass Monitoring Network (SeagrassNet) started in the Western Pacific but now has spread across 126 sites in 33 countries (Short and Coles 2015). This global protocol aims to preserve the valuable seagrass ecosystem by increasing scientific knowledge and public awareness of this threatened coastal ecosystem, through a web-based data reporting system. These protocols monitor seagrasses using permanent transects within intertidal meadows. Seagrass-Watch has a systematic way of sampling along the transect using quadrats at intervals of 5m while SeagrassNet uses pre-determined quadrats along the transect. At the regional level, the Western Indian Ocean Seagrass Network (WIOSN) was established in 2017. One of the objectives of the network is the harmonization of survey methods across the WIO region.

To monitor marine megafauna, a specific protocol was developed for sea turtles and is being applied. However, despite efforts to monitor marine mammals and sharks, no specific protocols

have been established. This protocol will be the first in Kenya to develop a monitoring protocol for marine mammals and sharks.

- **Kenyan Protocol for Marine Protected areas (MPAs)**
- **justification**

The existing ecological monitoring efforts have been in existence for a significant time. However, different organizations adopt different monitoring methods, often limiting meaningful comparisons and understanding of prevailing conditions. This protocol therefore seeks to standardize monitoring methodologies, better understand, and represent emergent ecosystem dynamics, better understand ecosystem seasonality and variability. The information is geared torwards the establishment of a robust marine ecological monitoring for long term sustainable and adaptive management and conservation of the delicate marine ecosystems and the associated fauna.

- **Intended users and expertise level**

The methods described in this protocol are targeted at an intermediate level of monitoring capacity or expertise. The intermediate level is often targeted at technical staff in an institution such as protected areas, and non-governmental organizations, where there are resources available to maintain this level of expertise and undertake periodic (usually biannually) field surveys for monitoring reefs. Intermediate level of expertise covers a broad continuum, but in general ongoing training and dedicated staff are necessary to allow periodic collection of reliable, but it is not necessarily required to invest in scientific training. However scientific supervision or involvement to the monitoring design and program and training of staff is helpful or necessary for data analysis and interpretation as well as reporting. More importantly, this protocol focuses on key variables needed or essential for tracking performance of MPAs.

- **Monitoring sites and/or stations**

Choosing a monitoring site is an essential part of the process of monitoring, and once a site has been selected it should be fixed for the duration of the monitoring program. In general, monitoring under the processes covered in this manual has already been underway, so several sites and stations are already selected. However, in upgrading a monitoring program, there may be opportunities to select additional sites. More importantly, selecting key habitats and representative locations for monitoring should be done by an expert, to maximize the comparability of sites in the monitoring program. Fish, macro-invertebrates, and benthic surveys should be done at the same sites.

- **Frequency of surveys/sampling**

For most purposes in coral reef monitoring, annual monitoring has been found to be adequate to track long term changes in benthic structure and invertebrate/fish populations. It is essential that samples are collected in the same season each year (within 1-2 months) to avoid seasonal differences (which may be significant for algae and fish). The timing of samples should be set by accessibility and safety constraints in the monitoring area, when the water and winds are calmest and least unpredictable, with good visibility conditions. In the WIO, this is generally just before

and during the northeast monsoon (November to April, with a period of difficult winds in the middle, around January).

- **Underwater Visibility correction**

Visibility error correction will be employed for all the techniques described herein. This will involve the use of a secchi disc deployed horizontally and vertically at 2-meter depth. Where visibility is below 5 m, the survey should not be carried out. The following entails a description of the methodologies that may be used under different circumstances.

- **Overview**

The health of coral reefs is measured through an assessment of the structure of benthic (coral, other invertebrate and algal communities) and fish communities. The results of reef health monitoring can be used as a baseline assessment of an area, and if done repeatedly using the same or comparable methods, can provide information on the effectiveness of MPAs to:

- protect the health and biodiversity of benthic communities.
- maintain or improve the abundance, size, and biomass of reef fish especially those species which are targeted by artisanal or commercial fishers.

This document covers the core methods that are currently applied in the region and used in the international scientific literature (English et al 1997, GCRMN plus i.e., beyond the scope of initial GCRMN guidance in the late 1990s/early 2000s). This guide is designed so that there is one standard basic monitoring protocol that should be applied as a minimum at each MPA site

While the manual gives significant guidance on implementation of a method, site selection within and outside MPAs, etc., a scientist with many years of experience should always be involved in guiding the field surveys programme.

Fisheries monitoring has remained a significant tool for management of fishery resources in the Western Indian Ocean (WIO) region, despite diverse challenges involved. In the wake of enforcement and deterrence of non-compliance on illegal unreported and unregulated (IUU) fishing, data collection and reporting of fishery resources is embodied in the Fishery Management and Development Act (No. 35 of 2016), and the Wildlife Conservation and Management Act (No. 47 of 2013). Conservation strategies require an accurate estimate of the state and current trends of a given ecosystem[M1] .

This protocol is because KWS has already established rationale for long-term monitoring of coral reefs in MPAs, and has demonstrated to be useful:

i) Bia-annual reef monitoring at 6 MPAs in Kenya

ii) Over ten years data used for GCRNM reporting in MPAs

iii) Scientific publications (e.g. Hashim thesis)

i) Given the growing interest in coral reefs and seagrass ecosystems conservation in MPAs, there is a need for harmonized monitoring protocol that allows standardized collection of data is paramount for accurate and reliable assessment of health and trends-which thereby allows for management practices to be adapted as needed (Delaval et al., 2021). Further, periodic monitoring have the potential to greatly improve the relevance of monitoring to park managers and other stakeholders, and to address the complex interactions between marine ecosystems (coral reefs and seagrass) and people (Obura et al., 2019).

The focus in MPAs is mostly on benthic, followed by fish and macroinvertebrates

- **Assessment Design**
- **Coral Reef & Seagrass Fish Abundance and Biomass Assessment**
- **Introduction**

The monitoring of reef fishes is critical as it provides a good overview of the ecosystem status. The high mobility of fish allows for rapid reaction to physical and ecological changes, making them important indicators of stressors in an ecosystem (Béguinot, 2021; Piria et al., 2019; Pratchett et al., 2018; Robinson et al., 2019a; Robinson, et al., 2019b). Select herbivorous and invertivorous species have also been documented to play important roles in strengthening coral reef resilience, making them important indicators of ecosystem status (Dwita et al., 2022; Green et al., 2009; McClanahan & Muthiga, 1989; Putra et al., 2018). Therefore, the frequent monitoring of changes in fish assemblages provides the critical information necessary to inform management decisions in an MPA.

- **Fish Indicators of Coral Reef Ecosystem Health**

A healthy reef should support a diversity of fish functional groups: from piscivores (fish eaters) to herbivores and planktivores (Kawaka et al., 2016). Indicators of species (or family) diversity will therefore be used, including species (or family) richness, density, biomass, Shannon-Weiner (Shannon & Weaver, 1949) and Simpson diversity indices (Simpson, 1949). While increases in species diversity implies a healthier ecosystem, reduced diversity is related to physical stressors, including sea surface temperature increase, pollution, or unsustainable fishing practices (Béguinot, 2021; Piria et al., 2019).

Additionally, the following key parameters will also be assessed:

1. **Herbivory**. The parrotfish family (Scaridae) and the rabbitfish family (Siganidae) will thus serve as the indicators for scraper and grazer herbivores, respectively (Green et al., 2009; Said et al., 2019). Herbivorous fish serve as indicators of coral reef ecosystem resilience (Adam et al., 2011). They scrape and graze on turf and filamentous algae, respectively, thereby giving coral reefs a competitive advantage. This helps accelerate the recovery of coral reefs following bleaching events (Khalil et al., 2013).

2. **Overfishing**. The Redlined Triggerfish (*Balistapus undulatus*) is an indicator for sustainable fisheries (McClanahan & Muthiga, 1989). Blooms of sea urchins have been documented to occur where overfishing takes place. This is owing to the excessive take of herbivorous fish, competitors of the sea urchins, and

reduced top-down control from the natural predator of sea urchins - *Balistapus undulatus.* Increased *Balistapus undulatus* species could therefore indicate sustainable fishing practices.

3. **Corallivory.** The butterflyfish family (Chaetodontidae) is an indicator of a healthy coral reef ecosystem as a positive correlation has been established between the two (Faricha et al., 2020; Hamuna et al., 2019). Therefore, increased butterflyfish densities and species diversity could indicate a healthier coral reef ecosystem.

To monitor the status of fish community assemblages in MPAs along the Kenya coast. The specific objectives include:

1. Assess temporal and spatial changes in fish species composition (species diversity, trophic levels and functional diversity)
2. Estimate and monitor trends in the abundance and biomass of indicator species by size over time

- ***Tools and Methods***
- ***Robust Sampling Methods***
- ***Fish Belt Transect***

This method aims to count (quantify) the abundance and community composition of fish on a transect. Belt transects measuring 5m by 50m are laid parallel to the shore across all the survey sites. The number of transects laid per site may vary between four to six depending on the size of the reef being assessed, covering both coral reefs and seagrass habitats. During the sampling exercise, the data collector swims/dives over a 50m line tallying fish counts per size classes for individuals seen within 2.5meters to his/her right and left hand sides (figure 1). Either visual census or cameras may be employed for this technique (English et al., 1997; Hill & Wilkinson, 2004; Obura, 2014). Since fish move rapidly, the data collector has to be careful not to count the same group of fish twice along the transect.

It should be noted, however, that the laying of the transects is expected to cause a disturbance to the normal behavior of fish assemblages in the assessment area. This may affect the data collected during the exercise. The transects are therefore left to settle for 5-15 minutes to allow for fish to resume normal behavior before beginning the sampling exercise. Alternatively, the data collector may swim ahead with a buddy tagging behind laying the transect. The buddy is to notify the data collector once the 50m mark is reached (English et al., 1997; Obura, 2014).

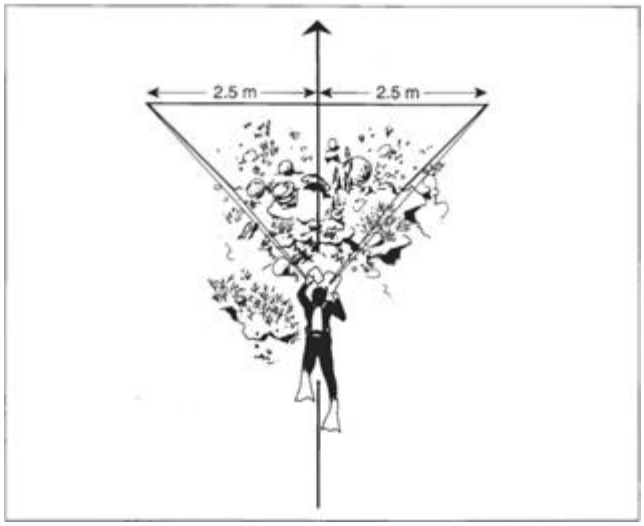


Fig 1: An illustration of a diver employing a belt transect to record fish information over a coral habitat (English et al., 1997).

This method is the most used in the region and generates high resolution data. However, it is time consuming, and should be used where time and resources are sufficient. Variables recorded during this exercise include: counts of individual fishes identified at least to family level, size classification to 5 size class bins (<9cm, 10-19cm, 20-29cm, 30-39cm and >40cm). Additionally, the individuals recorded should ideally be identified to species level. However, family level identification may still be used where capacity is lacking. See annex xx for the families assessed through this technique.

Identification: the taxa commonly used for fish surveys in the WIO have been determined through experience, and are shown in the appendix?. I dentification at the familiy level is the most basic and is sufficient for general management information.

Equipment required: 50m long transect tapes; slates/pencils and datasheets; fish models to practice fish length estimations underwater.

Field personel: I observer and I tape layer

- ***Rapid Sampling Methods***
- ***Timed Swims***

This is a visual census technique, and it is preferable in instances where the target/primary species are not sufficiently abundant in the belt transect surveys, or where the habitat does not allow for the use of belt transects (Bass & Miller, 2003; Hill & Wilkinson, 2004). It involves having a data collector swim at a constant speed through an imaginary 5m wide tunnel, where the length of the transect is determined by the length of time swam. The time is thus recorded at both the start and end of the swim. However, the timer must be stopped temporarily whenever a stop is made to assess larger schools of fish, or to assess crevices in coral reefs, rocks and rubble.

The Variables recorded during this exercise include the individual fish species counts, distributed into 5 size class bins (<9cm, 10-19cm, 20-29cm, 30-39cm and >40cm). See annex xx for the families assessed through this technique.

- ***Manta Tows***

This technique involves the towing of two scuba divers behind a boat at a constant speed (~1.5 knots) (Hill & Wilkinson, 2004). Each diver holds onto a bridle connected to a boat by a tow line. The bridle is outfitted with survey equipment, including a Geographic Positioning System (GPS) device, still photo cameras and/or video cameras. The survey commences with the deployment of divers where the starting time and GPS waypoint tracking is activated. Once the divers reach the bottom, they signal the team on the boat (using a telegraph), who commence the tow. The towboat is maintained 1m above the bottom.

The sampling units include 5 minute segments, each with a 1-minute circle survey and a 4-minute transect. The circle survey entails the recording of species larger than 50cm in total length through a 360° scan under the water. The tow is carried out in a 5m wide belt transect. At the end of the survey (cumulatively 50 minutes and roughly 2km combined for all the sampling units), the divers alert the team on the boat using a telegraph to stop the tow. The end time is recorded at this point, and the waypoint tracking is stopped.

The variables recorded during this exercise include fish species counts, species distribution per habitat and species lengths estimated into 9 size bins (table 1). This technique is useful for the sampling of larger species with larger homing ranges, and the rapid coverage of vast seagrass beds and coral reefs in short durations of time. See annex xx for the families assessed through this technique.

Code	Length category (cm)
1	20-34
2	35-49
3	50-74
4	75-99
5	100-149
6	150-199
7	200-249
8	250-299
9	300 and over

Table 1: Fish size distribution bins codes for the Manta Tow fish data collection method (Hill & Wilkinson, 2004)

Define MPAs in introduction

Mentioned in justification

- **Coral Composition, Cover, Extent and Bleaching Assessment (Dr. Mwaura)**
- **Introduction**

During the workshop, the participants discussed and selected indicators to measure effectiveness of managing MPAs and chose those in the list below as 'common' indicators. Based on these results, the team determined the ecological indicators to be measured as below.

Table 1: Scientific monitoring protocols for scientists - GCRMN standard

General Objective	**Specific objective**	**Rationale/explanation**	**Variables/indicators**	**Measurable**	**Method**	**Other variables can be used from this**
To measure (quantify) the status of coral reefs	To assess the benthic cover and/or composition	Indicates the balance between corals and other benthic groups as an overall indication of reef status	Hard corals, Soft corals, Macroalgae/fleshy algae, Turf algae, Inverts, Halimeda, Seagrass, Coraline algae, Sand, Rubble, Dead coral, Recently dead coral, Silt	Percentage cover	PIT/LIT/Photo quadrat – Level 1	Identify suitable substrate for restoration
	To assess the coral community composition	Indicate the diversity of the coral community	Provides an oveview of the relative abundance of Coral genera, from rare to dominant	Percentage cover, relative abundance	PIT/LIT/Photo quadrat – Level 3 Time swim	Growth forms, resilience categories
		Provides details on the health of coral colonies	Gives an indication of the current health or Coral condition of the coral community	Percentage	counting and categorizing corals by condition along a 25m by 1m belt transect	Observations on coral bleaching, disease, presence of predators and threats such as crown of thorns.

	To assess the population of coral community structure	Provide detailed information on the hard-coral population and can show indications of past impacts by presence or not of large colonies	Adult size-class (>10cm)	Density and area (25m2) Percentage	counting and sizing (>10 cm) 23 pre-determined genera in a 25m by 1m belt transect	Identify potential areas for natural recovery identify sink and source areas
		Indicate the stability and recovery of a coral reef	Recruit density (<10 cm)	Density (per m2)	Counting recruits inside a 1m2 quadrat along a 25m by 1m belt transect at 5-meter intervals	
	To assess bleaching and mortality of coral	Monitoring the impact of bleaching	Coral bleaching	Density and area (25m2)	Permanent belt transects	Indicates susceptibility or recovery of reefs to warming sea surface temperatures

- **Benthic cover**

Benthic cover shows overall status of the coral reef by providing the proportion of corals in comparison to other benthic categories such as algae and soft corals. Benthic cover is one of the ocean variables that have been used over decades to show the status and trends on changes of coral reefs. Percentage matrix is used in defining the benthic cover.

- **Tools & Methods**

Benthic and coral cover can be assessed at three different levels. Level 1 involves look at the fifteen (15) major benthic categories. Level 2 quantifies major benthic categories and the growth forms. Level 3 entails

quantifying the major benthic categories and the cover of all coral genera observed. There are three different methods that can be used to quantify the benthic cover and are comparable.

- **Line Intercept Transect (LIT)**

Line Intercept Transects (LIT) are the most common method used and has been applied for generating long term data in Kenya. This method is easy and applicable mainly for fixed benthic cover objects covering certain proportion on the bottom of the reef. A 10 m transect is stretched in a straight line without consideration of width to estimate the percentage cover of benthic communities. At least six (6) transects at each monitoring station are required.

Equipment required: 10 m long transect tapes; slate/pencils and datasheets

Field personnel: at least 2 observers (snorkeling or scuba) are required with expertise in identification of coral reef benthic categories

Illustration of the method (to be done)

- **Point Intercept Transect (PIT)**

Point Intercept Transect (PIT) is a quicker and convenient data collection. It records individual points along a 50 m transect at an interval of 50 cm. For procedure, a 50 m transect is laid out at the bottom of the reef and benthic categories are identified at each of the predefined points (i.e., 50 cm interval). At least six (6) transects of 50 m at each monitoring station are required.

Equipment required: 50 m long transect tapes; slate/pencils and datasheets.

Field personnel: at least 2 observers (snorkeling or scuba) are required with expertise in identification of coral reef benthic categories.

Illustration of the method (to be done)

- **Photo quadrats**

Photo quadrats method works by taking still images of benthic substrates at random along predetermined path and depth. It is a much quicker method that allows the SCUBA diver or snorkeler to take benthic photos at the shortest time than LIT and PIT. However, it takes more time on desktop annotation of photo quadrats, therefore needs expertise and convenient annotation programme. A 25 m transect laid out at the bottom of the reef and photos are taken along both sides of the transect at an interval of 3 m. Photo quadrats are taken vertically about 0.7 – 1 m above the benthic substrates. At least 40 photos are required at each monitoring station and only 24 photos would be randomly selected for further analysis.

Equipment required: Underwater camera and transect tapes.

Field personnel: at least 2 observers (snorkeling or scuba) are required with skilled and stable in underwater photography

Photo quadrat annotation: at least 1 person with skills of using annotation programme (e.g., CPCe, CoralNet etc) and identification of coral reef benthic categories.

Illustration of the method (to be done)

- **Coral community**

This informs on population parameters of hard corals on the reef. This includes; adult corals, coral recruits and healthy conditions. Information on coral colony is obtained, providing a useful indicator of coral community stability. Large average size indicates no recent disturbance; small average size indicates recent disturbance and recolonization, recruit can provide information on the recovery potential and coral condition informs the possible threats on corals.

- **Tools & Methods**
- **Adult coral size class**

Provide detailed information on the hard coral demography (i.e., growth and mortality). Adult coral size class data gives information on different sizes of corals present at a particular area at a given time. For monitoring, this will be important to show the changes in the sizes of coral colonies over a period of time. A 25 m by 1 m belt transect is used to count coral colonies from a selected coral genera. The counts of colonies are tallied in six (6) size classes in centimeters (cm): 11-20, 21-40, 41-80, 81-160, 161-320, >320.

Equipment required: 25 m transect tapes, 1 m tape measure or a calibrated 1 m stick, slate, pencil and data sheets.

Field personnel: at least 2 observers (snorkeling or scuba) are required with expertise in identification of corals at genus level

- **Coral condition (bleaching & diseases)**

Provide detailed information on the health of coral colonies. Coral condition data gives information on different threats to corals such as coral bleaching, predators, diseases and sedimentation. A 25 m by 1 m belt transect is used to count coral colonies by healthy condition from a selected coral genera.

The counts of colonies are tallied in eight (8) healthy conditions namely: healthy, pale, bleached, partial-dead, disease, sediment on-top, predation and others.

Equipment required: 25 m transect tapes, 1 m tape measure or a calibrated 1 m stick, slate, pencil and data sheets.

Field personnel: at least 2 observers (snorkeling or scuba) are required with expertise in identification of coral condition at genus level.

- **Coral recruits**

Coral recruits are colonies which are <10 cm in diameter. They indicate the stability and recovery of a coral reef. The quantify coral recruits, counting and tallying is done inside a 1m2 quadrat along a 25m by 1m belt transect at 5-meter intervals (i.e., 6 quadrats per transect). Standard size classes (in cm) to be used are: 0-2.5, 2.6-5 and 5.1-10.

Equipment required: 25 m transect tapes, 1 m by 1 m quadrat, 1 m tape measure or a calibrated slate using standard size classes, slate, pencil and data sheets.

Field personnel: at least 2 observers (snorkeling or scuba) are required with expertise in identification of corals at genus level.

- **Analysis and presentation**
- **Seagrass Cover Assessment**
- **Introduction**

Seagrasses are submerged marine flowering plants that grow in the nearshore environments. They occur from the upper estuarine to marine environments. Seagrass beds are among the most widespread and productive coastal ecosystem types that occur either as monospecific or mixed stands. Factors regulating the physiology and morphology of seagrasses include temperature, salinity, waves, currents, depth, substrate, light, nutrients, water currents, wave action and epiphytes. Other factors include the availability of seeds and vegetative fragments and the anthropogenic inputs that inhibit available plant resources including excess nutrients and sediment loading. Their depth range is controlled by availability of light for photosynthesis while their survival is ensured at sites that are sheltered from wave action. Therefore, their distribution is affected by a combination of these parameters.

The dominant seagrass species along the Kenyan coast is Thalassodendron ciliatum, which attaches to both hard and soft substrates. Zostera capensis is a rare species in seagrass ecosystems and it is categorized as vulnerable in the IUCN red list hence there is need to conserve it. All these seagrass species are widely distributed along the Kenyan coast and most of them occur as mixed species meadows. The diversity of seagrass species in these mixed meadows means that the seagrass ecosystems are comprised of different growth forms which lead to an extremely complex and diverse multispecies environment that hosts a wealth of biodiversity.

The continued provision of ecosystem goods and services of seagrass meadows is influenced by anthropogenic and natural threats including potential climate related effects. Anthropogenic impacts include destruction by boat anchors, destructive fishing methods, dredging, oil pollution and increased land runoff. Natural disturbances that affect seagrass beds include overgrazing by sea urchins and fish triggered by reduced predation of fish as a result of overfishing of urchin predators and eutrophication. Potential climate change effects include sea level rise and global warming.

Seagrasses normally have a defined zonation pattern from shallow areas to deeper sediments. Thalassodendron ciliatum and Enhalus acoroides for instance grow in deeper sediments and are considered to be climax species. Halodule uninervis and Halophila ovalis are transitory species considered as pioneer species growing rapidly and surviving well in unstable or depositional environments. Cymodocea serrulata occurs normally in deeper sediments.

Table 1 : Table showing zonation of seagrass along the Kenyan coast

Successional stage	**Intertidal**	**Subtidal**

Pioneer community	*Halophila ovalis* *Halodule wrightii* *Cymodocea rotundata* *Zostera capensis*	*Halophila stipulacea* *Halodule uninervis*
Climax community	*Cymodocea serrulata* *Thalassia hemprichii*	*Thalassodendron ciliatum* *Syringodium isoetifolium* *Enhalus acoroides*

- **Methodology**

Sampling of at least 30% of the total area should be adequate to be a representative of the site under study. This will be done to cover each zone adequately i.e. intertidal, shallow subtidal, deeper subtidal which will be towards the reef (seagrass species and distribution differ within these zones). Three 50m transects, 20-25m apart parallel to the shoreline will be used for each zone at all sites. However, the number of transects may be increased for highly patchy seagrass beds.

- **Assessment Parameters**

It should be noted that the indicators of a healthy seagrass meadow are more subjective, location specific and could change with time. Therefore, assessment of baseline conditions is important for each location to enable establishment of baseline conditions that can be used as indicators for the long-term monitoring. This protocol includes non-destructive methods of seagrass monitoring that cover the plant population as well as the biotope. It is recommended to measure the parameters bi-annually depending on the situation for each bed and the locally available means.

Table 2: Monitoring parameters for seagrass habitats

Monitoring level	**Parameter**	**Frequency**
Plant population	Cover (%)	Biannually
	Shoot density (shoots m^{-1})	
	Canopy height (cm)	
Biotope	Type of bed (mixed or monospecific)	Biannually
	Size of bed (Area coverage)	
	Patchiness of bed (patchy, aggregated, continuous)	

Necessary Materials and equipment

1. Boat with safety equipment
2. Dive equipment and personnel
3. 50m transect line
4. Underwater slates for writing
5. GPS device
6. Underwater camera where available
7. Tide table

8. 50cm by 50cm stainless steel quadrat divided into four squares
9. 25cm by 25cm stainless steel quadrat divided into four squares
10. Notebooks and pencils
11. Tailor tape measure
12. Plant population

- **Percentage cover**

Percentage cover will be estimated using the 50cm by 50cm quadrat on a scale of 0-100% in quadrats along laid transects for each zone at intervals of 5m along the transect. Estimates of seagrass cover and any other substrate present (total cover and then cover by each species) will be determined on a percent cover scale (0-100%) using 11 quadrats per transect.

- **Shoot density**

Shoot density by species will be determined within the 25cm × 25cm quadrat along laid in the 50m transects for each zone at intervals of 5m along the transect. At least 11 quadrats per transects will be used with shoot counts of each of the species within a quadrat counted.

- **Canopy height**

Canopy height will be determined using a tape measure (cm) within the 25cm by 25cm quadrat only for the climax species which include Thalassia hemprichii, Thalassodedron ciliatum, Enhalus acoroides, Cymodocea serrulata, Syringodium isoetifolium. For every species present in a quadrat measure 5 leaves from the sediment to the tip of the leaves 5 stipes from base at sediment to the tip. The leaves to be measured should be the ones closest to the 4 corners and the center point of the quadrat. Where less than 5 leaves for a particular species are encountered in a quadrat, measure all the leaves in the quadrat.

- **Biotope**
- **Type of beds**

This will be described for each site sampled in the field notes to be able to establish where we have mixed stands and where we have monospecific stands (stands of a particular species). Mixed stands will comprise seagrass beds with more than one species while monospecific stands will comprise seagrass beds with only one species.

- **Size of beds**

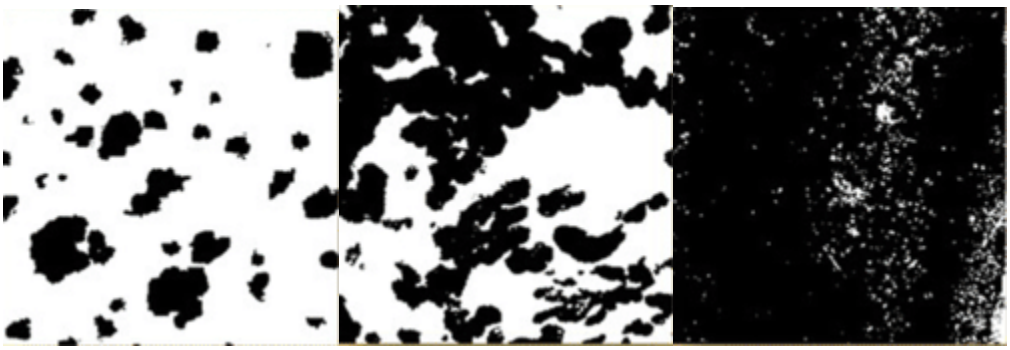
This will be estimated using the GPS location around the seagrass beds to determine the area covered by seagrass within a defined larger area (e.g. Park, Reserve, Community Conserved Area). If resources are available drone images can be used to determine the spatial extent of the seagrass meadow.

- **Patchiness of beds**

This will be described for the different beds sampled in the field notes as described below.

1. **Isolated seagrass patches**- The majority of area within the meadows consisting of unvegetated sediment interspersed with isolated patches of seagrass

2. **Aggregated seagrass patches**- Meadows comprising numerous seagrass patches but still featuring substantial gaps of unvegetated sediment within the meadow boundaries
3. **Continuous seagrass cover**- Meadows comprising continuous seagrass cover interspersed with a few gaps of unvegetated sediment.



Isolated seagrass Patches	**Aggregated seagrass patches**	**Continuous seagrass cover**

Analysis, presentation and interpretation of data

Monitoring level	Parameter	Aspect	Analysis	Presentation	Interpretation
Population level	Cover	Species composition	% mean substrate specific cover	Total increase/decrease = ((recent % cover – past(baseline) % cover) / past(baseline) % cover) *100	This can inform anthropogenic disturbances since these can lead to shifts in seagrass ecosystems from a condition where climax communities dominate to a degraded state where pioneer species dominate. Some specific seagrass e.g. *Enhalus acoroides* also favour high nutrient areas
		Macroalgal cover	% cover	Total increase/decrease = ((recent % macroalgal cover – past(baseline) % macroalgal cover) / past(baseline) % macroalgal cover) *100	Higher macroalgal cover e.g. Cyanobacteria (Blue green algae) can inform increased nutrient input
	Shoot density		Species specific mean density of shoots expressed per m^2	Total increase/decrease = ((recent Shoot density per species – past(baseline) shoot density) / past(baseline) shoot density) *100	Reduced shoot density and canopy can inform changes in water quality or herbivory pressure
	Canopy height		Range and mean canopy height for the	Total increase/decrease = ((recent Mean canopy of dominant	

			dominant species expressed in cm	species – past(baseline) canopy of dominant species) / past(baseline) canopy of dominant species) *100	
Biotope	Type of bed		Mixed or Monospecific	Mixed or Monospecific	Changes in the type of bed over time can inform shifts in seagrass ecosystems such that a shift from monospecific meadows to mixed meadows could indicate an intermediate stage of succession. The species combination varies with depth, substrate and herbivory. Herbivory is the major factor determining the seagrass bed structure in most meadows along the coastline.
	Size of bed (Area coverage)	Bed extent	Area covered by seagrass within a defined larger area (e.g. Park, Reserve, community conserved area) expressed in Km^2.	Total increase/decrease = ((recent area - past area (baseline))/past area) *100	These will inform increased herbivory, sedimentation or physical destruction (e.g. Moorings, Beach seining, Trampling etc.)

	Patchiness of bed		Patchy, Aggregated or Continuous	Patchy, Aggregated or Continuous	

- **Macroinvertebrate Assessment** (Levy, Songok & Wambi)
- **Introduction**

Monitoring of the marine ecosystem is an important component of management that provides up-to-date information on which to base decision-making and application of management interventions and initiatives. As a management tool, the protocol will be useful in assessing the diversity, distribution, density and threat levels of macro-invertebrates in Marine Protected Areas (MPAs) and Community Managed Areas (CMAs) for effective management of the coral reef ecosystem. This manual therefore, has been developed in consistent with other coral reef monitoring protocols jointly by institution with support from WWF Kenya, Marine component, through the BIOPAMA project to guide in monitoring of macro-invertebrates within the MPAs and CMAs.

- **Objectives**

The general objective of the manual is to equip MPA managers and staffs with skills and knowledge to carry out regular monitoring and surveys within the MPAs and CMAs.

Its specific objectives are to:

1. To assess changes in macro-invertebrates diversity, density and distribution within the MPAs and CMAs bi-annually
2. To determine status and trends for selected indicator macro-invertebrates for the condition of MPA
3. To provide reference point data on macro- invertebrates for comparison with other or altered marine ecosystems
4. To provide macro-invertebrates specific data for measuring management interventions and goals towards a healthy coral reef ecosystem.

- **Rationale**

Ecological monitoring is a quantitative assessment of the status and trends of ecosystems. In the management of MPA, it is fundamental in providing data and information for effective and appropriate decision making for management. MPA managers in Kenya have in time memorial, been confronted with increasingly complex and challenging issues in management of marine resources and thus require a properly designed scientific tool for monitoring, data collection, analysis and interpretation that will help in decision-making and consequent application of appropriate management interventions. This monitoring protocol is therefore developed as the scientific tool to fill the gap in acquisition of quality monitoring data for macro-invertebrates in MPAs

- **Methodology**
- **Monitoring sites**

The bi-annual monitoring of macro-invertebrates alongside other monitoring components, will be carried out in all MPAs within coast conservation areas i.e. in Kiunga, Malindi, Watamu, Mombasa and Kisite Marine parks and reserves during North East Monsoon wind (between October and March) and South East Monsoon wind (between April and September).

- **Data Collection**

Data collection will employ observational method that will involve identification of macro-invertebrates species along a 50 by 5 m long belt transect. This method aims to count (quantify) the abundance of key macro-invertebrates on a transect. Here a swimmer/observer will lay a transect of 50 m length parallel to the shore at a random start point counting key macro-invertebrates observed along a 2.5 m on either side to give a total count width of 5m.

This will be combined with circular point's plot of a radius of 1 meter for sea urchins. Identification of macro invertebrates at species level at MPAs will be done by research scientists for the key indicator species for management oriented monitoring. However, this will not be applicable to communities monitoring in CMAs

It is good to note that invertebrates (sea urchins, Lobsters, octopus) are quite cryptic and may inhabit crevices in the reef. Observers therefore should swim at a constant speed and carefully examine crevices. For areas with high densities then application of quadrats may be more appropriate.

- **Equipment and personnel**

50 m long transect tapes, one-piece circular point plot of 1 m length rope slate/pencils and datasheets and identification sheets where possible.

Three (3) or more observers are required, one (1) for laying the transect, another one (1) to assess sea urchins and another one (1) for assessing other macro-invertebrates. However, /tape/ transect layer, may be done in conjunction with fish or benthic transects.

- **Monitoring indicators and variables**

Monitoring will focus on key macro-invertebrates families for Community monitoring groups and to species level for research scientists and MPA personnel.

Key macro-invertebrates indicator species will be chosen based on their morphology and niche as documented in literature.

Common name	**Scientific family name**	**Role in the ecosystem**
Sea urchin	Echinometridae	Bioeroders
Sea cucumber	Holothuriidae	Deposit feeders
Star fish	Asteriidae	Predators
Shells (Lambis, Tiger cowri, Triton shell, bull mouth)	Molluscs	Predators
Giant clums	Tridacnidae	Suspension feeders

Crown of thorns	Acanthasteridae	Bioeroders
Octopus	Octopodidae	Predators
Lobsters	Palinuridae	Omnivores

- **Variables to be assessed are;**

i) Density

This is measured by the total counts of species per 250m2 for all other macro- invertebrates, however, for urchins a circular point' plot of a radius of 1 meter will be placed at an interval of 10 m along the 50 m transect belt.

ii) Distribution

This refers to the manner in which a biological taxon is spatially arranged by its geographic limits in its range. This will be measured by the total number of the different species observed in a site in comparison to the total number of similar species in other sites in a given MPA or CMA

iii) Diversity

This refers to the number of different species present in an ecosystem and their relative abundance. This can be measured by the combination of species richness (the number of species present) and species evenness (the relative abundance of each species

- **Data Analysis and presentation**

For analysis of the species densities, one may add the total number of macro-invertebrates per species in all transects, then calculate the average densities by dividing the total count for each species by the number of transects.

Analysis of species diversity can be done by counting the number of macro-invertebrates species per site (Species richness) and calculating the relative abundance of each species.

Results will be presented in graphs and bar charts

- **Threshold and recommendation**

As we continue monitoring, we shall compare the findings and monitor the population trends and dynamics of macro-invertebrates. This will give an indication of ecosystem status and ultimately guide effective management interventions for MPAs and CMAs.

- **Mega Fauna Assessment**
- **Background**

Kenya's coastline extends for about 640 km, from the Kenya – Somali border at Ishakani in the north to Vanga in the south on the Kenya – Tanzania border. The Kenyan coastline hosts 25 species of marine mammals including dugongs (*Dugon dugong*), humpback whales (*Megaptera novaeangliae*), sharks and rays (*Elasmobranch sp.*) and dolphins (*Tursiops spp*). In addition, all the five species of sea turtles and

several species of sharks also occur in Kenyan waters. A protocol for sea turtles in Kenya has been developed separately and this manual does not include sea turtles.

Dugongs (*Dugong dugon*) are a herbivorous marine mammal inhabiting shallow tropical and sub-tropical coastal waters of the Indian and western Pacific Ocean. Historically, the dugong inhabited the entire shallow coastal waters of Kenya. Heard of hundreds have been recorded in the 1960's. However, their numbers have dropped sharply over the years (WWF-EAME, 2004).

Dolphins are a distributed and diverse group of aquatic mammals. They are an informal grouping within the order Cetacea. 14 species of dolphins are found in Kenyan waters (NEMA, 2009), the most common species being the near threatened Indo-Pacific bottlenose dolphin (*Tursiops aduncus*). This specie occurs a few kilometers offshore in small pods of 2-5 individuals to very large pods of hundreds. The second most common specie is the endangered humpback dolphin (*Sousa Plumbea*). Other dolphin species found in the area included the Spinner dolphins (*Stenella longirostris*), regularly sighted further offshore in mega pods of several hundreds. The Spotted dolphin (*Stenella attenuata*) common dolphin (*Delphinus delphis*) are also found but are rarely seen.

Whales, like dolphins are marine mammals and belong to the order cetacean. Eight species of Baleen whales, 2 of Sperm whales and 13 of Toothed whales occur in the WIO region. In Kenya Bryde's whale (*Balaenoptera edeni*), Humpback whale (*Megaptera novaeangliae*) and Minke whale (*B. acutorostrata*) and blue whale (*Balaenoptera musculus*) have been reported. Kenya is thought to be part of the migration route for the Humpback whale. The humpback is the most reported whale species in Kenya, (known as Chongoe in Kiswahili) often associated with destruction of fishermen gill nets. (NEMA, 2009).

Marine megafauna are generally good indicators of ecosystem health and play a critical role in regulating the functions of marine ecosystems. The marine aerial census is an efficient tool for identifying marine megafauna species distribution, estimating the population, and identifying threats. The last extensive national marine aerial census in Kenya was done in 1997. A focused dugong assessment was done in 2016 – 2017 and targeted the south Kenyan coast and the north Kenyan coast areas. Due to the ongoing developments of port infrastructure, climate change and enhanced fisheries activities along the Kenyan coast, marine megafauna assessment is critical and marine aerial census is an effective tool as a targeted method for megafauna assessment. Other opportunistic methods are also important and complement the targeted assessments.

- **Methodology**
- **Aerial Census**

Marine megafauna aerial census is a useful tool in assessing the populations of highly migratory species found in the shallow coastal marine waters. **The aerial census,** which should be conducted at least four times in a year (one survey a month) following a strip transect method described by Marsh & Sinclair (1989) and used by Findlay et al. (2011) in the surveys conducted in the Bazaruto region of Mozambique and replicated in Kenya in 2016 and 2017. The area to be covered includes the entire Kenyan coastline stretching from the Kenya – Tanzania border in the South to the Kenya – Somalia border in the North. Survey flights are to be flown as a series of East to West or West to East transects in a progressive North

to South direction, between the coast and the 30 isobaths. The surveys will be conducted in the morning between 700h and 1200h. Line spacing between transects will be 1 km. The lengths of transects shall vary according to the coastal orientation and water depth often ranging between 6 – 33 km. All survey transects shall be flown following the aircraft's Global Positioning System (GPS), at an altitude of 500ft and a speed of approximately 80 knots, in a high-wing configuration aircraft. Each flight can last for approximately 4-5 hours, depending on the position of the sun, with the early sunrise period being the best period for visibility.

The survey crew shall consist of tandem team of a pilot, two observers on each side of the aircraft and a data recorder. A single observer shall search the entire visual observation area (outwards from the most vertical perspective that could be gained) from the rear seats on each side of the aircraft. The data recorder, who shall seat in the forwards starboard position, shall log flight paths, altitude, survey efforts, sighting parameters and weather conditions and direct the pilot.

Sightings made while in transit will be recorded as secondary sightings, whereas sightings made during transects will be recorded as primary sightings. Secondary sightings will be excluded from abundance estimation or density analysis. Positions of efforts and sightings will be recorded using a handheld GPS. On making a sighting, the observer shall measure the perpendicular distance from the survey track lime to the dugong sighting using an inclinometer to measure the dip azimuth angle to the group, or by assigning a sighting to distance bins marked by tape on the aircraft wing. All the information on a dugong sighting (including number of animals, occurrence of calves in groups and the sighting angles) shall be immediately related by the observer to the data recorder, who is operating the GPS and recording sighting data. Data and associated GPS positions will immediately be downloaded on completion of each of the surveys and entered spreadsheets for initial verification analyses.

The survey leader will be responsible for keeping a regular check on aircraft speed and altitude (measured by pressure altimeter), and for recording details of weather condition, including wind speed and direction, cloud cover (oktas), the nature of the sea surface (Beaufort scale), the times at which each transect began and ended, and the observations of the rear-seat observers, including the relative amounts of glare off the surface of the water on either side of the aircraft.

The rears-seat observers shall communicate with the survey leader via a two-way intercom system connected to one track of a two-track tape recorder. They shall report the following information in standardized format at the time of first sighting: marine mammal/megafauna species, group size, number of calves, behavior (swimming, idling, feeding diving), and number of individuals at surface.

- **Dedicated boat-based surveys.**

Dedicated boat-based surveys are seasonal and conducted during the Northeast Monsoon winds between (November to April). A four-member research team will be used to scan the water surface over 180◦ field of vision from the beam to the bow of the boat. Each observer covered a 45◦ subsection of the field of vision.

Team members rotated every 15 min during the survey. Non-systematic transects will be carried out during the surveys.

Once the dolphins/Whales have been sighted, data recorder will log in GPS coordinate at the start of the survey as well as the weather condition. Other team members will observe the animals to identify species, composition, behaviour, and reaction to other boats (especially dolphin watching tour boats). In addition, photo- Identification and behaviour will be recorded.

- **Data analysis**

Perpendicular distances of megafauna groups from the track line will be calculated for sightings as d.tan (θ), where d is the aircraft altitude at the time of sighting and θ is the horizon minus the dip azimuth angle of the sighting from the horizon (measured at the time of sighting abeam by handheld inclinometer).

The DISTANCE software (version 6.2) will be used to fit a hazard-rate model to the perpendicular distances grouped into 0.05 nautical mile intervals to give the sighting probability density function f(0) and its variance V[f(0)]. All the perpendicular distances of sightings, left-truncated at 0.1 nautical miles due to the low detection probabilities directly under the aircraft, will be used.

This pooled sighting probability density function will be initially applied to all surveys combined, to estimate abundance over the entire series of surveys. Given that the application of a generic effective search width will bias results of the individual surveys (upwards under good sighting conditions and downwards under poor sighting conditions), a further set of analyses will be performed on the data collected during the five surveys carried out under optimal sighting conditions.

- **Population size estimates**

The marine megafauna population size (N) in the surveyed area will be calculated as:

$$N = \frac{[A.n.s.f(0)]}{[2L.g(0)]}$$

where,

A, surveyed area

n, is the total number of groups sighted during effort

s, is the mean size of groups

L, is the total length of the search track or transects

g(0), which is the probability of detection of groups of animals on the track line is equal 1

- **Density distribution maps**

Density diagrams adjusted for sampling intensity will be produced with ArcGIS package. A grid coverage (2.5 or 5 km2) will be combined with the coastline coverage. The corrected number of dugongs and the transect length in each grid cell will be calculated. The density in each grid cell will be calculated as follows:

Density/km2 = corrected number of dugongs sighted in cell/survey area in cell, where survey area = transect length in km x transect width (i.e., 0.4 km).

Data for all analyses will be corrected densities/km2 based on mean group sizes and the estimated correction factors for perception and availability bias. The densities will be transformed (log10 x+1) for analysis to equalize the error variances.

For species guide please see this link :
https://www.researchgate.net/publication/331248561_CETACEAN_IDENTIFICATION_CARDS_for_Indian_Ocean_Fisheries

(5) (PDF) Cetacean Research and Citizen Science in Kenya. Available from:
https://www.researchgate.net/publication/352443427_Cetacean_Research_and_Citizen_Science_in_Kenya [accessed Mar 10 2022].

- Data management and analysis
- **Data entry, verification, and editing**

All the data stored in Dictaphones shall be Trans-scripted into data sheets. The data recorded in the data sheets and that in the Dictaphones should be checked for accuracy of recording by a team that was not involved in transferring the data from the Dictaphones to data sheets. Once verified, the data should be entered in to excel spread sheets. The entered data should also be checked by a team that was not involved in entering it into the excel spread sheets. Any entry errors should then be corrected. The excel spread sheets are then merged to acquire one master spread sheet. This is the dataset that is imported into ArcGIS and merged with the waypoints and tracks data from the GPS to form the main metadata. It is then available for preparation of summary results and preparation of distribution maps.

- Metadata

The cleaned and final metadata shall be organized into one shape file with all attributes stored therein. The metadata should then be uploaded to the data storage server for secure storage. Additional files should be shared with the Head of Wildlife Populations and Habitat Dynamics. Duplicate shapefiles will be stored in hard drives by the respective office in charge of wildlife data.

- Data security and archiving

The raw data and the cleaned metadata are stored in the WRTI data storage server. Additional data shall be stored in hard drives by respective offices.

- Analysis methods

The data shall be analyzed following standard processes as described by Jolly (1969), Norton-Griffiths (1978), Douglas-Hamilton (1996), Zar (1996). For total and sample aerial census, summary tables of the number of wildlife species counted in the census area shall be tabulated. Non-parametric statistics shall be used to test the observed number of wildlife species compared to previous census to discern whether population changes are statistically significant during the periods under review (Zar, 1996). For sample aerial census, analyses procedures describe by Jolly (1968) and outlined by Norton-Griffith (1978) shall be followed. Transects and species distribution maps shall be prepared using ArcGIS software following procedures described by ESRI (2020) or higher versions.

Where sampling has been undertaken and distribution of data collected is established to be normal, parametric analysis can be undertaken following procedures described by Zar (1996). If the computed distribution of the data is not normal, the data can be transformed as outlined by Zar (1996). This should be followed by use of parametric statistics to discern statistical significance of observations under investigations.

The interpretation of all analyzed data should follow procedures described by Zar (1996).

- Reporting
- Background

Census methods and level of search effort vary widely between census areas. Therefore, it is vital that census reports include detailed information on the methods used and the level of search effort adopted. This should include who was involved, what work was carried out and where, when (both date and time of day) and how the census was conducted, as well as the climatic conditions at the time. The census report should follow the standard format common to all scientific research. This will facilitate interpretation of the census results and replication of the study for comparative purposes. It is useful to record the GPS location of all sampling units and provide maps of the study area. Detailed descriptions of the habitat should be recorded. Information on the condition of the habitat at the time of the census should also be included, as this may be useful in later analysis. Documenting the habitat occupied by target taxa during the survey process, and a site description, will add value to the census. Documentation of observers and their skills is also important. Presentation of all mammal taxa recorded is essential as it can provide a measure of census effort and effectiveness.

It is important that reports contain suitable information to demonstrate the census was sufficient to draw the conclusions. Documenting the survey effort will be particularly important for species that might be present at very low abundance in the project area. Findings should be supported by information such as photos of equipment used during the census and habitat structure, photos/records of scat or other trace material, summary tables of the results from the census, and photographs of mammals that were counted during the census. Tabulated GPS coordinates of sites and equipment placement will allow precise determinations of occurrence within a project area.

Maps should be included that show the distribution of the species counted and any other feature of importance in the census area. Maps could also show the location of equipment placement such as trapping equipment, as well as GPS tracks of the transect path taken during active acoustic monitoring or searches. This will allow a better understanding and interpretation of census effort.

Reports should carry some justification of the census design, whether it be opportunistic, systematic or focused on certain likely habitats. This would include information on the habitat types present and the survey effort given to each. The design should also distinguish between known or potential foraging, breeding and commuting habitats. For species that might be present at very low abundance, it is important to describe the likelihood of presence based on habitat descriptions made as part of the survey. Explanations on the timing of the census, suitability of the weather, the speed and duration of transect travel and observations recorded should also be given.

Census data should be made available to National and County Governments and should be included in National Wildlife Database.

- Report contents

The census reports will have one standard report format. The report will include the following sections:

i) **Topic:** The topic should be short and precise. It should be catchy to attract readers to want to read the report. An example of a census report could be, "Population Trend of Large Mammals in the Fragmented Landscape of Tsavo Ecosystem"

ii) **Authors:** This should Name all the Authors who participated in developing the report. The first Author should have made the highest contribution in designing and developing the report. The authors list should be arranged according to contribution of each author. This will be determined by the lead author of the report. The last author is the overall supervisor of the census.

iii) **Table of Contents:** This section will show the pages of the sections inside the report.

iv) **List of Figures:** The section will list all figures in the report.

v) **List of Tables:** The section will list all the tables in the census report

vi) **List of photographs (Plates):** This section will list all photographs used in the report

vii) **Acknowledgements:** This section should recognize and thank those who supported the census to be undertaken successfully.

viii) **Introduction:** The section will introduce the report including the justification for the census, goal and specific objectives

ix) **Materials and methods:** This section will describe the census area, outline the sampling frame and sampling units, state the sample size and why use that sample size, describe how the data was collected and analyzed, sources of errors and outline any assumptions. Appropriate references should be included for literature reviewed on the census area, methods and data analysis tools and software used as well as interpretation that guides the interpretation of the data.

x) **Results:** This section should report on the findings after undertaking the census. It should be very precise and specific on the results. Where statistics are used, reports on these statistics should follow standard procedures of describing statistical results.

xi) **Discussion:** The section should provide a detailed comparison of the results with other results in the same area, other areas in Kenya and outside Kenya. Reasons for observed results should be provided in this section.

xii) **Conclusions:** Clear conclusions should be provided in the report. The conclusions are based on results obtained from the census and associated reasons for the observed results.

xiii) **Recommendations:** The report should also have clear recommendations. These are drawn from the results and reasons from the observed results. The recommendation are expected to guide management interventions and also identify other areas that require further research

xiv) **Reference:** All the references quoted in the report should be listed in this section. Standard referencing approach should be used. For our reports, we will adopt the referencing approach used by the African Journal of Ecology.

xv) **Annexes:** A list of annexes should also be included in the reports. This could include the concept developed to source for funding to undertake the census, list of participants during the census, raw census data, key and important photographs not included in the

report and general maps not included in the other sections of the report but are important to be part of the report.

- Reporting schedule

The reports should be prepared immediately after the census. Where the census exercise was time consuming and tiring, a break of 2-5 days could be necessary to allow the team to rest before they start data cleaning and report writing. Data cleaning and report writing for one census site should not take more than 10 days. The census team leader should ensure this schedule is strictly followed to facilitate provision of a draft report 14 days after the undertaking of the census is completed.

Once the draft report is available, it shall be shared with all the authors for comments. The authors will be given 5 working days to provide their comments to the lead report author. The lead author shall then incorporate the comments for a maximum of 3 days. Less days can be taken if only few comments are received. In consultation with the Director, WRTI and Deputy Director- Research and Development, the lead author shall then identify 3 external reviewers for review of the census report. The review by external team will be on "*pro bono*" basis. The reviewers will be requested to review the report within 14 days and return the comments to the lead author.

- Report distribution

It is important to share the final report to National Government Departments and Agencies, County Governments, Conservation Non-Governmental Organizations, Development Partners, National and International Institutions of Higher Learning, and Conservancies.

Electronic copy of the report will be uploaded to the Respective Wildlife Ministry, Kenya Wildlife Service and Wildlife Research and Training Institute Websites. An electronic copy will also be shared with other partners and institutions listed in Paragraph one above. They will be requested to upload the final report to their respective websites.

Hard copies will be shared with key entities that supported the Census as well as libraries of different institutions and partners in Kenya.

All technical reports should have an ISBN Number. The number will be applied from the Kenya National Library services. Two copies of the report shall be deposited with the National Library Services as a Policy and Legal Requirement in the Country.

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Annex 2: Sites for counting sitatunga in Western Kenya and Rift Valley

No	County	Site	village
1	Busia	Busia –Bunyala	Bumbamba
			Bulwani Island
		Bundalangi	Maduwa island
			Sio Port
2	Siaya	Yala Swamp	Lake sare
			Kanyaboli
			Namboyo
		Lake Victoria	Osieko beach
			Uhanya
			Misori beach
3	Kisumu		Dunga beach Kisumu and Impala A and B
			Kusa beach
			Koguta
		Ndere Island National Park	Main island
			Butiana swamp
			Othany village
			Nyamware
4	Homabay		Kendu bay seka
			Kamuga-Kowili village
5	Migori	River Kuja	Kabuto
6	TransNzoia	Saiwa Swamp National Park	Inside the park
		Outside Saiwa Swamp National Park	(Sinyerere swamp)
			Kipsaina-kitonyi bridge
			Kitale Nature Conservancy
	Uasin Gishu	Kigwal swamp	
		Kesses dam	
	Nandi	Kibateti swamp	

Annex 3: Legal frameworks related to wildlife census

Legislation under which public sector agencies operate, defines the role, responsibility and power of the agency to enable it to carry out a particular function. Partner agencies

must ensure they are acting lawfully. Some of the relevant laws and policies are listed below:

Main Statute	Role of Statute	Relevance of Statute
The Constitution of Kenya, 2010	Constitution is the supreme law of the Republic and binds all persons and all State organs at national and county levels of government	**Section 33 - Sub section 1(a –c):** Every person has the right to freedom of expression, which includes, freedom to seek, receive or impart information or ideas, artistic creativity; academic freedom and freedom of scientific research. **Section 35 - Sub section 1-3:** Every citizen has the right of access to information held by the State; and by another person and required for the exercise or protection of any right or fundamental freedom. **Section 46 – Subsection 1(a – d) and Sub section 3:** This Article applies to goods and services offered by public entities or private persons. It states that consumers have the right to the information necessary for them **Section 232- Sub section 1(f):** The values and principles of public service which include transparency and provision to the public timely and accurate information;
Wildlife Conservation and Management Act, 2013	An act of parliament to provide for the protection, conservation, sustainable use and management of wildlife in Kenya and for connected purposes.	**Section 5 - Sub-section 2 (g) parts (i-iv)** prescribe National Wildlife research and monitoring priorities and information systems. **Section 7 - Sub-section (*l*):** WRTI shall conduct and coordinate all research activities in the field of wildlife conservation and management and ensure application of research findings in conservation planning, implementation and decision-making. **Section 52 - Sub section 1(a) parts (i-iv)**: Collect and analyse wildlife data and information to support planning and decision-making by different stakeholders. **Section 60, 61, 62**
Environmental Management and Coordination Act, 1999, CAP 387, No 8 of 1999	An ACT of Parliament to provide for the establishment of an appropriate legal and institutional framework for the management of the environment.	**Section 9 - Subsection 2(h):** undertake and co-ordinate research, investigation and surveys in the field of environment and collect, collate and disseminate information about the findings of such research, investigation or survey.

Main Statute	Role of Statute	Relevance of Statute
		Section 50 (a-g): The National Environment Management Authority shall, in consultation with the relevant lead agencies, prescribe measures necessary to ensure the conservation of biological diversity in Kenya **Section 51 (a – f):** The Authority shall, in consultation with the relevant lead agencies, prescribe measures adequate to ensure the conservation of biological resources *in-situ* and issue guidelines for management and conservation of biological diversity. **Section 52:** The National Environment Management Authority shall in consultation with the relevant lead agencies prescribe measures for the conservation of biological resources *ex-situ* especially for those species threatened with extinction and issue guidelines for their management.
Environmental management and co-ordination (Amendment) Act, 2015	AN ACT of Parliament to amend the Environmental Management and Coordination Act, 1999	**Section 4.** On access to information. **Part 3A - Sub section 1 and 2:** which states that Subject to the law relating to access to information, every person has the right to access any information that relates to the implementation of this Act that is in the possession of the Authority, lead agencies or any other person.
Access to information Act, 2016	An Act of Parliament which is intended to give effect to the right of access to information by citizens as provided under Article 35 of the Constitution and provide a framework for public entities and private bodies to proactively disclose information that they hold and to provide information on request in line with the constitutional principles.	**Section 4 - Sub section 1 (a & b):** States that every citizen has the right of access to information held by the State and another person and where that information is required for the exercise or protection of any right or fundamental freedom. **Section 4 - Sub section 2 (a &b):** every citizen's right to access information is not affected by any reason the person gives for seeking access; or the public entity's belief as to what are the person's reasons for seeking access. **Section 4 - Sub section 3:** Access to information held by a public entity or a private body shall be provided expeditiously.

Main Statute	Role of Statute	Relevance of Statute
		Section 4 - Sub section 4: Act shall be interpreted and applied on the basis of a duty to disclose and non-disclosure shall be permitted only in circumstances exempted under section 6. **Section 5 (a)-**On disclosure of information by public entities. **Part (vii):**a public entity shall provide sufficient guidance to enable any person wishing to apply for information under this Act to identify the classes of information held by it, the subjects to which they relate, the location of any indexes to be inspected by any person; **Section 6 - Sub section 1(a-h), and Sub Section 2 (a-j &i):** stipulates limitation of right of access to information related to security, intelligence information, and covert operations. **Section 6 - Sub section 4**: Public entity or private body may be required to disclose information where the public interest in disclosure outweighs the harm to protected interests as shall be determined by a Court. **Section 6 - Sub section 5:** A public entity is not obliged to supply information to a requester if that information is reasonably accessible by other means **Section 9 - Sub section 4 (a-c):** As soon as the information access officer has made a decision as to whether to provide access to information, he or she shall immediately communicate the decision to the requester **Section 17 - Sub section 1 and sub section 2 part (a & b):** on management of records by public entities **Section 19:** Where any information provided by a public entity or private body to an applicant under section 11 (on providing access to information) was supplied to the public entity or private body by a third person, the

Main Statute	Role of Statute	Relevance of Statute
		publication to the applicant of any defamatory matter contained in the information shall be privileged unless the publication is shown to have been made with malice.
Copyright Act 2014	An Act of Parliament to make provision for copyright in literary, musical and artistic works, audio-visual works, sound recordings, broadcasts and for connected purposes	**Section 23:** stipulated conditions of copyright by virtue of nationality or residence, and duration of copyright. **Section 24:** Copyright by reference to country of origin, where Copyright shall be conferred by this section on every work, other than a broadcast which is eligible for copyright **Section 25:** Copyright in works of Government and international bodies. **Section 26 – Part (a, d, &h):** On nature of copyright in literary, musical or artistic works and audio-visual works **Section 31 - Sub section 1 & 2:** On First ownership of copyright **Section 35:** On infringement, it stipulates the situations under which infringement occurs and action to be taken.
Industrial Property Act 2001	An Act of Parliament to provide for the promotion of inventive and innovative activities, to facilitate the acquisition of technology through the grant and Regulation of patents, utility models, technovations and industrial designs, to provide for the establishment, powers and functions of the Kenya Industrial Property Institute and for purposes incidental thereto and connected therewith.	Part III - Part XVIII

1.1. Coral Reef Fish Data Collection Sheet

Underwater Ecological Monitoring

Fish Density Data Collection Sheets

Meta Data:

Transect No. _____ Date: _____

Area: _____

Site: _____

Data Collectors: _____

Env'tal Data

Secci visibility: _____ Chlorophyll a: _____

Cloud cover: _____ Surface temp: _____

Wind speed: _____

Transect Data

		Size class tallies				
Family	**Species**	**<9**	**10-19**	**20-29**	**30-39**	**>40**

1.2. Seagrass Species of Kenya

Thalassodendron ciliatum (Tc)

	● Long erect shoots with up to 10 leaves on the terminal portion ● Leaves up to 15cm long and 6-12cm wide with a serrated margin. ● Leave sheath about 2cm long ● The stem bears scars of shed leaves. ● The rhizome is sparsely branched with erect shoots at every fourth internode. ● Grows commonly in the upper part of the sub tidal area. ● Characteristic of areas with high turbulence e.g. channels. ● It is a climax community.

Enhalus acoroides (Ea)

	• Commonly in bays and deep channels. • Favour high nutrient areas • Rhizome up to 1-1.5cm in diameter, covered by fibrous remains of leaf sheaths. • Thick un-branched roots and inconspicuous erect shoots. • Leaves are long (about 1m) with parallel venation.

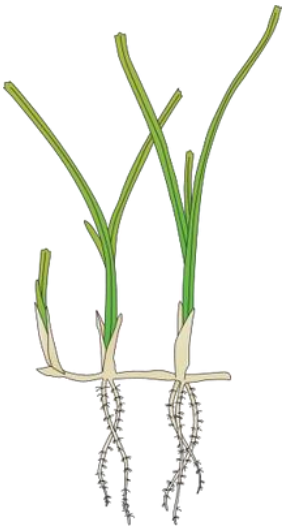
Syringodium isoetifolium (Si)

	• Rhizomes are reddish, with 2-4 cylindrical leaves produced from short erect shoots. • Erect branches with Leaves about 2mm in diameter. • The rhizome is monopodially branched. • Grows on fine sediments in the upper sub-tidal areas. • Usually grows in association with other seagrasses (rarely monospecific) • It's a middle level community (i.e. not pioneer and not climax)

Halodule uninervis (Hu)

	• Rhizome reddish and stiff, producing short erect shoots with a few linear leaves. • Leaves 1-2mm wide and 6-15cm long. • Most of the leaves end in two marginal teeth and with a central vein in a blunt protuberance. • Leave sheath is about 2cm long. • On soft bottom in the intertidal and in mangrove areas. • Is mainly a pioneer species

Halodule wrightii (Hw)

	• Very similar to *Halodule uninervis*, but leaves are longer (30cm) and only have marginal teeth. • On sandy and muddy substrates in the intertidal. • Pioneer species.

Cymodocea rotundata (Cr)

	• Leave sheaths 2-4cm long, accumulating at the base of the erect shoots • When the sheaths are shed, they have a circular scar on the stem. • Leaves 8-15cm long and 3-4cm braod. • Leave tip rounded and without obvious serrations along the margin. • Forms extensive beds on soft substrata and coral sand in the lower intertidal.

Cymodocea serrulate (Cs)

	• General features as the *Cymodocea rotundata* but leaves with a serrated margin. • Leaves leave an open scar on the stem when shed. • Occur in the same habitat as the *Cymodocea rotundata.* • Has broader leaves than *Cymodocea rotundata* and is lighter in its green colour.

Halophila ovalis (Ho)

	• Small and delicate with a stolon-like shoot about 1-2mm in diameter. • Leaves are petiolate and occur in pairs on each node. • Leaves about 4cm long and 1cm wide, not serrated. • They have a prominent petiole, 1-3 cm ling. • A sub-tidal species found down the depth of 15m, but may also occur in intertidal areas which are muddy. • It is a pioneer species.

Halophila stipulacea (Hs)

	• Similar to *Halophila ovalis* but leaves are linear and strap shaped, 3-6cm long and 3-7mm wide. • Leaves have a serrate margin and an inconspicuous petiole. • It is a sub-tidal species.

Thalassia hemprichii (Th)

	• The rhizome is coarse and covered with brownish scales. • Erect shoots are short, with groups of up to 6 linear leaves. • Leaves are 10-30cm long and 5-6cm wide.

	• Reddish remains of old sheaths are present at the base of the green leaves. • Very common species and grows extensively on soft substrata in the intertidal. • The leaves are darker than *Cymodocea serrulata* and have black spots on them. • It is a middle level community.

Appendix: Aerial Count Datasheet

Pilot		**Aircraft Reg:**				**Block No.**	
Front Seat Observer							
Rear Seat Observer(left)						**Date**	
Rear Seat Observer(right)							
Take off Time		Start count Time			Stop count Time	Land Time	
Way Point No.	**Region I/O**	**Species**	**Estimate**	**L/R**	**Photo No**	**Photo-count**	**Comments**

Appendix 4.1.12: Calibration measurements for observers Datasheet

Plane Number	**Observer name**	**Pilot**	**FSO**	**Plane model**	**Plane Reg**	**Eye Mark-Low**	**Eye Mark-HI**	**Wing Strut Inner Mark**	**Fuselage to Inner Rod End**	**Wing strut outer mark**	**Fuselage to Outer Rod End**

Appendix 4.1.13: GPS download tracking datasheet

Date	Asst Tag(GPS)/ Serial Number	Issue To	Label on MakTape	MapDatum	XcordATFlag	Ycordat Flag	EleleatFlag	File_Name

Data sheets

Appendix 4.1.21: Transect count datasheet

Date:		Transect Name:	Sheet No:…..…….
Observers:			
Transect length:	Season:	Place of count:	
Start time:	Stop time:	Transect direction:	Block ID:

Species	Time	Way Point No.	UTM Coordinates		Direction of sight	Distance to sight	Total No.	General Activity	Age& Sex structure									Body cond.	Visibility (Good, Fair, Poor)	Habitat type	Comments
			X	Y					A			S A			Juvenile						
									M	F	U	M	F	U	M	F	U				

Body condition: Good-Full body, Fair- Backbone ridge & ribs visible, Poor-Ridge, ribs, shoulder & hip bones visible

Habitat: F-Forest, WL-Woodland, CBL-Closed bush land, OBL-Open bush land, GL-Grassland, SW-Swamp

General Activity: Feeding, Resting, Drinking, Grooming, Fleeing.

Block count datasheet

Date:	Block Number	

Observers:														Sheet No:….. of…….
Block Number:				Season:							Place of count:			
Start time:				Stop time:							direction:			Block ID:
Species	Time	Way Point No.	UTM Coordinates		Direction of sight	Distance to sight	Total No.	General Activity	Age& Sex structure			Body cond.	Visibility (Good, Fair, Poor)	Habitat type	Comments
			X	Y					A	SA	Juvenile				