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Kavango Zambezi Trans Frontier Conservation Area
Angola Botswana Namibia Zambia Zimbabwe

KAZA

AN AERIAL SURVEY OF ELEPHANTS AND OTHER LARGE HERBIVORES IN THE KAVANGO ZAMBEZI TRANSFRONTIER CONSERVATION AREA

VOLUME I: RESULTS AND TECHNICAL REPORT

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Executive Summary

Following several years of preparation, the KAZA Elephant Survey (2022) commenced on 22 August 2022 and ran until 28 October 2022. The primary objective of the survey was to obtain a relatively precise and accurate estimate of the number of African savanna elephants (hereafter elephants) in the Kavango Zambezi Transfrontier Conservation Area (KAZA TFCA), by synchronising data collection, particularly in areas of transboundary elephant movement. Secondary objectives included estimating populations of elephant carcasses and other large herbivores (both wild and domestic), as well as recording their spatial distribution. The results presented in this report include maps and tables illustrating the spatial distribution and abundance of the surveyed species, as well as information on survey execution and compliance with standards.

The survey area covered 60% of the KAZA TFCA. It was divided into 179 strata, sampled during 195 flights using seven fixed-wing aircraft. Systematic transect sampling was the primary method used, while stratified block sampling was employed in two strata with rugged topography (i.e., Matusadona Hills and Kanyati Highlands, in Sebungwe, Zimbabwe). Additionally, three reconnaissance flights were conducted in areas considered to have the potential to support elephants.

The overall sampling intensity was 6.9%, ranging from 2.6% to 56.0% between strata, with higher intensities where higher densities of elephants were expected (based on previous survey data). A total of 398 hours spread over 68 days were spent collecting data on 2404 transects, totalling 67,390 km in length. Overall, the mean height above ground level (AGL) on transect was 91.8 m (SD = 6.5) with a mean ground speed on transect of 171.5 $km.hr^{-1}$ (SD = 5.8), resulting in a search effort of 1.12 $minutes.km^{-2}$.

The survey met the percentage relative precision (PRP) target of ≤10% for the elephant population estimate and adhered well to the recommended CITES MIKE Aerial Survey Standards, with few deviations as documented in the report. The survey was effectively synchronised across international boundaries within a sufficiently narrow time frame, ensuring a reliable assessment of this transboundary population.

The main results of the survey include:

- A total estimated population of 227900 (±16743) elephants in the KAZA TFCA, with a PRP of 7.34%.
- A total estimate of 26641 (±1645) elephant carcasses, resulting in an overall carcass ratio of 10.47%. This suggests a high level of mortality which warrants further investigation as a potential warning sign for the health and stability of the elephant population.
- Population estimates for other surveyed wildlife species in the KAZA TFCA survey area are as follows: buffalo 78264 (±18882), giraffe 12771 (±1789), hartebeest 10905 (±2538), hippopotamus 17006 (±2940), impala 100028 (±12695), roan 7428 (±1917), sable 39966 (±7386), wildebeest 22245 (±8496) and zebra 88250 (±28059).
- For the same survey area, the size of the domestic livestock herd was estimated at 736426 of which 73% were cattle (536623 (±54295)) and 24% sheep and goats (173746 (±22940)), resulting in a ratio of 1.16 wild animals to 1 domestic animal in the area.

Comparing the results of this survey with those of recent former surveys, the overall elephant population in the KAZA TFCA appears to be stable, with some areas showing population increases, others remaining stable, and some possibly experiencing a decrease. This heterogeneity across the survey area is likely reflective of past management regimes and varying ecological and anthropogenic contexts. Similarly, variations in elephant mortality are observed both between and within countries in the KAZA TFCA survey area, as measured by the carcass estimates and carcass ratios. This underscores the importance of not only considering the specific context of each area and country when analysing elephant population trends and mortality rates, but also promoting transboundary cooperation and alignment of management strategies in the KAZA TFCA to ensure the long-term survival of elephants and other large mammal species.

The primary and secondary objectives of the KAZA Elephant Survey (2022) were successfully achieved, providing valuable information on the population and distribution of elephants and other large herbivores in the KAZA TFCA. These results will be useful for informing conservation efforts and wildlife management in the region.

To create a useful reference for future synchronised surveys of the KAZA TFCA, we have included comprehensive information on both the successes and challenges encountered during the survey and suggest ways to improve this ambitious exercise in future attempts. We have provided extensive data in the report itself as well as its various appendices and a second volume, which will enable access to all details required to conduct a repeat survey. The compiled database, including raw data from each flight, has been archived and will remain under the safekeeping of the KAZA Secretariat and the Partner States.

Acknowledgements

We express our sincere gratitude to the KAZA Secretariat and the governments of the Partner States - Angola, Botswana, Namibia, Zambia, and Zimbabwe - for commissioning and supporting this survey. The collaboration between their respective ministries and wildlife departments was integral to the success of the project. We are particularly thankful for the Partner States' efforts in mobilising ecologists and wildlife officers who made up 50% of the field teams, as well as their assistance in securing the necessary permits for the survey to take place. The Partner States helped with management and oversight of all aspects of the survey through the appointment of aerial survey Focal Points, and we are grateful for their input and assistance. Botswana's DWNP kindly made office space available in their regional wildlife office in Kasane that served as the operations room for the survey. Additionally, we would like to acknowledge the Civil Aviation Authorities of the Partner States for granting us permission to conduct this low-level survey across their territories.

This project was made possible through the generous funding from the following organisations: the Paul G. Allen Family Foundation, the German Federal Ministry of Economic Cooperation, the Dutch Postcode Lottery and its Dreamfund project, USAID's Combating Wildlife Crime in Namibia and the Kavango-Zambezi Area project, the UK Foreign and Commonwealth Development Office, the Sharjah Environment and Protected Areas Authority UAE, the US Fish and Wildlife Service, World Wildlife Fund US, Panthera and the EU funded CITES MIKE Programme.

We express our deepest appreciation to all the individuals and organisations who have contributed to the success of this survey.

Without the hard work and dedication of the field teams, we could not have achieved our goals. We extend our heartfelt thanks to each member of the teams for their tireless efforts, often under challenging field conditions. We are especially grateful to the field team leaders, Twakundine Simpamba, Jaco van der Westhuizen, Debbie Gibson, and Kevin Dunham, for their expertise, leadership, and guidance throughout the project. We also extend our appreciation to TOSCO and CIRAD for making some of their staff available for the survey.

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We extend our thanks to all those people of Angola, Botswana, Namibia, Zambia, and Zimbabwe whom we met along the way and who shared our enthusiasm for the project. Lastly, we thank the elephants for capturing our attention and taking us on a great adventure for months. You, magnificent pachyderms, have achieved something as great as your size by convincing five countries to come together to protect the KAZA TFCA. The region would, without a doubt, be a sadder place without you.

Abbreviations and symbols

AGL	Above ground level (usually with reference to flying height)
ANOVA	Analysis of Variance
APN	African Parks Network
CI	Confidence Interval
CR14	The all-carcass ratio, for carcass categories 1 to 4
CR12	The fresh and recent carcass ratio, for carcass categories 1 and 2
CIRAD	*Centre de coopération Internationale en Recherche Agronomique pour le Développement* (French Agricultural Research Centre for International Development)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DNPW	Department Of National Parks and Wildlife, Zambia
DWNP	Department of Wildlife and National Parks, Botswana
EOSS	Earth Observation Solutions and Services
ER	EarthRanger, a data visualization and analysis software for protected area management
FSO	Front Seat Observer
ft	Foot, or feet (aircraft flying height is measured in feet)
GEC	Great Elephant Census
GMA	Game Management Area
GPS	Global Positioning System
GPX	GPS exchange format. A standard file format for GPS data interchange.
GIS	Geographic Information System
ICCF	International Conservation Caucus Foundation
IUCN	International Union for Conservation of Nature
KAZA	Kavango-Zambezi
KES	KAZA Elephant Survey
kts	Knots (nautical miles per hour)
m	Meters
MIKE	Monitoring the Illegal Killing of Elephants
mph	Miles per hour
MWS	Modernising Wildlife Surveys
NASA	National Aeronautics and Space Administration
PPF	Peace Parks Foundation
PRP	Percentage Relative Precision
QGIS	Quantum Geographic Information System
R	R is a programming language for statistical computing and graphics
RSE	Relative Standard Error
RSO	Rear Seat Observer
SD	Standard Deviation
TFCA	Transfrontier Conservation Area
TOSCO	Tourism Supporting Conservation
UAE	United Arab Emirates
WWF	World Wildlife Fund
ZPWMA	Zimbabwe Parks and Wildlife Management Authority

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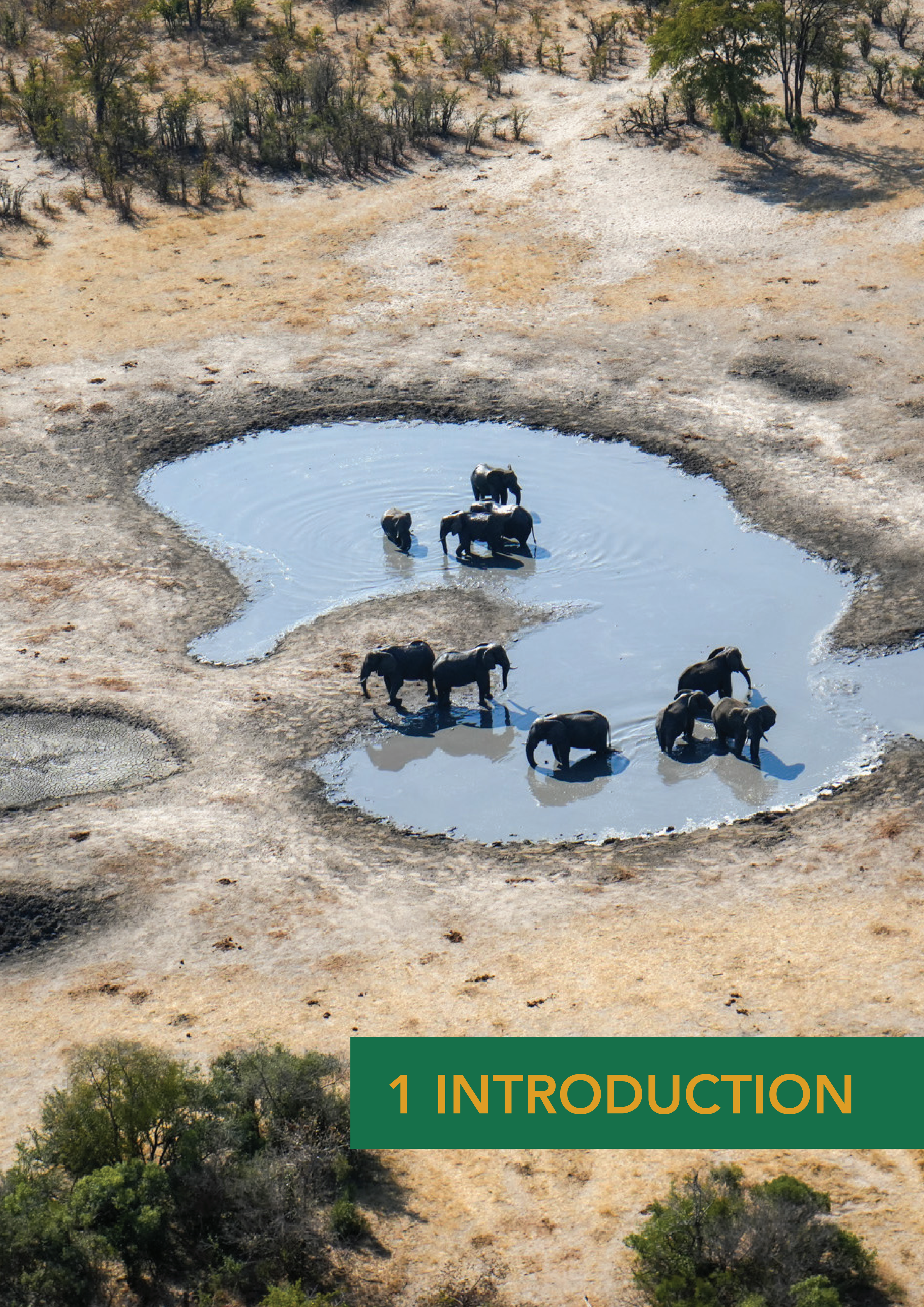


1 INTRODUCTION

1. Introduction

1.1. Background

1.1.1. The Kavango-Zambezi Transfrontier Conservation Area

The Kavango-Zambezi (KAZA) Transfrontier Conservation Area (TFCA), hereafter also referred to as KAZA, is among the largest terrestrial conservation areas in the world, occupying approximately 520,000 km^2 within the borders of the five Partner States of Angola, Botswana, Namibia, Zambia, and Zimbabwe. It lies in the Okavango and Zambezi River basins, and encompasses a variety of ecosystems, including savannas, woodlands, arid environments, and wetlands. The KAZA TFCA comprises a network of conservation areas, including 19 national parks (covering approximately 160,900km^2) and other protected areas such game reserves, wildlife and game management areas, safari areas, forest reserves, community conservancies, and world heritage sites (comprising approximately 236,000km^2) (Fig. 1.1) (KAZA Secretariat, 2014). These protected areas provide critical habitat for a wide array of wildlife, and the region is known for its high biodiversity. As a result, the KAZA TFCA is an important area for eco-tourism and provides economic benefits for local communities. Additionally, the region is home to a population of approximately 2.5-3 million people, including rural communities, indigenous groups, and urban residents. Many communities depend on the natural resources of the region for their livelihoods, such as pastoralism, hunting, fishing, and agriculture. The KAZA TFCA is thus a complex socio-ecological setting that is shaped by the interplay between human communities, protected areas, and the natural environment.

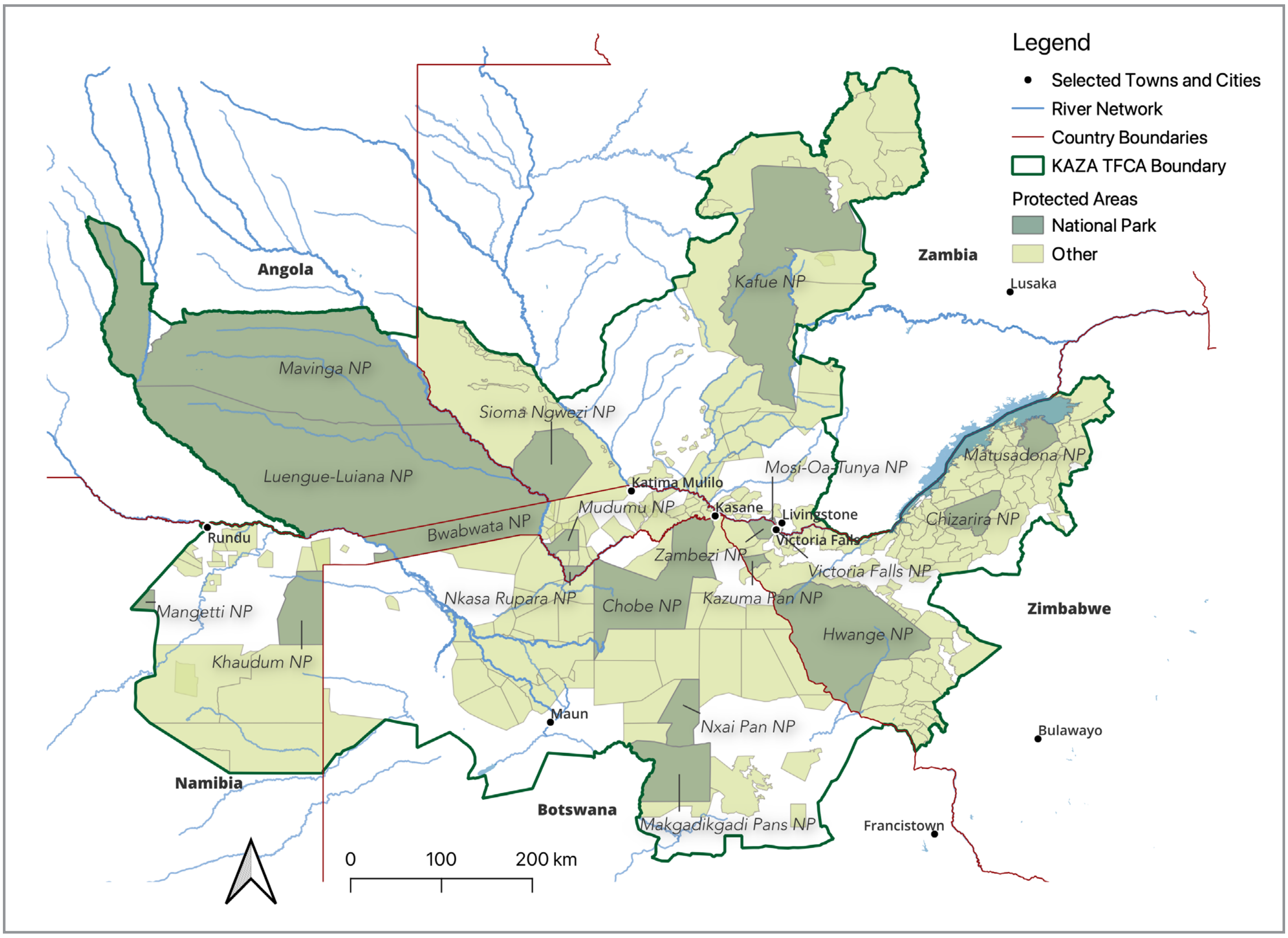


Figure 1.1: Map of the Kavango Zambezi Transfrontier Conservation Area, showing National Parks and other protected areas.

The KAZA TFCA was established through a joint effort by the governments of the five Partner States. The process formally commenced in 2006 with the signing of a Memorandum of Understanding (MoU) defining the objectives, principles, and the general framework for cooperation among the signatories for the protection and sustainable management of the transfrontier area and its resources. This step served as the foundation for its official establishment, which was marked by the signing of the KAZA TFCA Treaty by the governments of the Partner States on 18 August 2011 in Luanda, Angola. The Treaty established the TFCA as a legal entity and set up the institutional framework. The management and administration of the KAZA TFCA is overseen by several governance structures, including the Ministerial Committee, Committee of Senior Officials, Joint Management Committee (JMC), Secretariat, and National Committees. The Secretariat is responsible for coordinating and driving the day-to-day activities associated with the planning and development of the KAZA TFCA and is accountable upwards through the JMC.

The goal of the KAZA TFCA is "To sustainably manage the Kavango Zambezi ecosystem, its heritage and cultural resources based on best conservation and tourism models for the socio-economic wellbeing of the communities and other stakeholders in and around the eco-region through harmonisation of policies, strategies and practices."

1.1.2 Elephants in KAZA TFCA

The elephant population in the KAZA TFCA is of great importance, as it constitutes more than 50% of the remaining African savanna elephants (*Loxodonta africana*) found on the continent and is the largest contiguous transboundary elephant population globally, with prior estimates between 184,000 and 243,000 elephants (Thouless et al., 2016). Conserving and managing this elephant population is not only important for ecological sustainability but also for the social and economic well-being of the region.

To this end, KAZA developed the Strategic Planning Framework for the Conservation and Management of Elephants (KAZA Secretariat, 2019). This Framework was approved by the KAZA Ministers in April 2019 and later reinforced by the resolutions of the Heads of State during the Kasane Elephant Summit in May 2019. It aims to ensure the long-term survival of the species with the vision that KAZA's elephants are conserved to the benefit of people and nature within a diverse and productive landscape.

The objectives of this Framework are to 1) facilitate the development of an integrated land use planning process to secure long-term ecosystem integrity and connectivity of KAZA's elephant population, 2) maintain and manage KAZA's elephants as one contiguous population, 3) promote and support co-existence of humans and elephants for ecological, social and economic benefits, 4) reduce the illegal killing and trade in elephants and elephant products, and 5) establish a high-level decision-making process on which to build the planning framework for conserving elephants in the KAZA TFCA.

1.1.3 Previous aerial surveys

Numerous surveys have been conducted in various parts of the KAZA TFCA since its creation in 2011, aimed at assessing the in-country status of elephant and other wildlife populations. Table 1.1 presents a summary of the most recent dry season surveys conducted in the KAZA TFCA.

Aerial surveys are typically carried out independently in each KAZA country with little standardisation, resulting in variations in time of year, area covered, standards, and methodologies used. This can make KAZA TFCA totals, as well as comparisons across sites, and over time challenging. That is an important motivation for the implementation of this survey.

Table 1.1: Recent dry season aerial surveys conducted in the KAZA TFCA.

Country	Region	Survey Year	Data Source
Angola	South-eastern Angola	2015	Chase & Schlossberg, 2016
Botswana	Southern Botswana Northern Botswana	2012 2018	DWNP, 2012 Chase et al., 2018
Namibia	Kavango Zambezi region Khaudum NP and neighbouring conservancies	2019 2019	Craig & Gibson, 2019a Craig & Gibson, 2019b
Zambia	Kafue NP & neighbouring GMAs Sioma Ngwezi NP and GMAs Mosi-oa-Tunya NP, Kazungula	2021 2019 2008	DNPW, 2021 DNPW, 2019 DNPW, 2009
Zimbabwe	North-west Matabeleland Sebungwe region Chizarira NP and Chirisa Safari Area (portions of Sebungwe)	2014 2020	Dunham et al., 2015a Dunham et al., 2015b Dunham, 2020a

1.1.4 Background to the KAZA Elephant Survey

A priority activity listed in the Strategic Planning Framework for the Conservation and Management of Elephants is the need to conduct KAZA TFCA-wide (i.e., in all five countries) synchronised aerial surveys, to determine the numbers and seasonal distribution of elephants. This need was reaffirmed as a priority during the Kasane Elephant Summit, prompting a workshop (held in October 2019), where research staff and survey biologists from the KAZA countries gathered with external experts in Kasane to revise the CITES MIKE Aerial Survey Standards (CITES Secretariat, 2020) and to develop an indicative survey design for the first ever KAZA-wide coordinated aerial survey.

The 2019 workshop participants agreed that a KAZA Elephant Survey should be conducted as a unified effort and not as a "separate component approach". The workshop addressed considerations such as the design, planning and implementation of such a survey, recognising that this large-scale and complex undertaking requires the participation of many different organisations and individuals across the five partner countries.

Two central tenets were adopted at the workshop; 1) centralised coordination and management of the survey is required and that this would be overseen by the KAZA Secretariat, and 2) the survey must be carried out in accordance with the updated CITES MIKE Aerial Survey Standards Version 3.0 (CITES Secretariat, 2020).

A report (Dunham, 2020b) was produced following the workshop, outlining the agreements reached by participants regarding the survey's design, planning, execution, and dissemination of results. The report includes a comprehensive initial survey design and an approximate budget for the project, serving as a key guide for the planning and implementation of the survey.

1.2 Survey objectives

The primary objective of the KAZA Elephant Survey (2022) was to obtain a relatively precise and accurate estimate of the total number of elephants within the KAZA TFCA, utilising techniques that were both cost-effective and feasible within a reasonable timeframe. Specifically, the goal was to obtain a percentage of relative precision (PRP) less than or equal to 10% of the final population estimate.

The survey's secondary objectives included estimating the populations of elephant carcasses and other large herbivore species (both wild and domestic), as well as to record the spatial distribution of elephants, elephant carcasses, and other large herbivores within the KAZA TFCA.

Additionally, the survey aimed to achieve these objectives using standardised methods, as set out by the CITES MIKE programme, which were technically sound and repeatable.

1.3 Survey preparation

The KAZA Elephant Survey (2022) required extensive preparations and collaboration among the five KAZA Partner States. In July 2021, the project management team for the survey was established and funds were raised to support the project, with the World Wildlife Fund (WWF) chosen as the grant manager and implementation partner by the five partner countries.

In November 2021, the position for an Aerial Survey Coordinator was advertised. During the following February, a team approved by the Partner States was appointed to supervise, coordinate, and undertake the planning, execution, data analysis and reporting for the aerial survey in close collaboration with the KAZA Secretariat and the KAZA Partner State Focal Points.

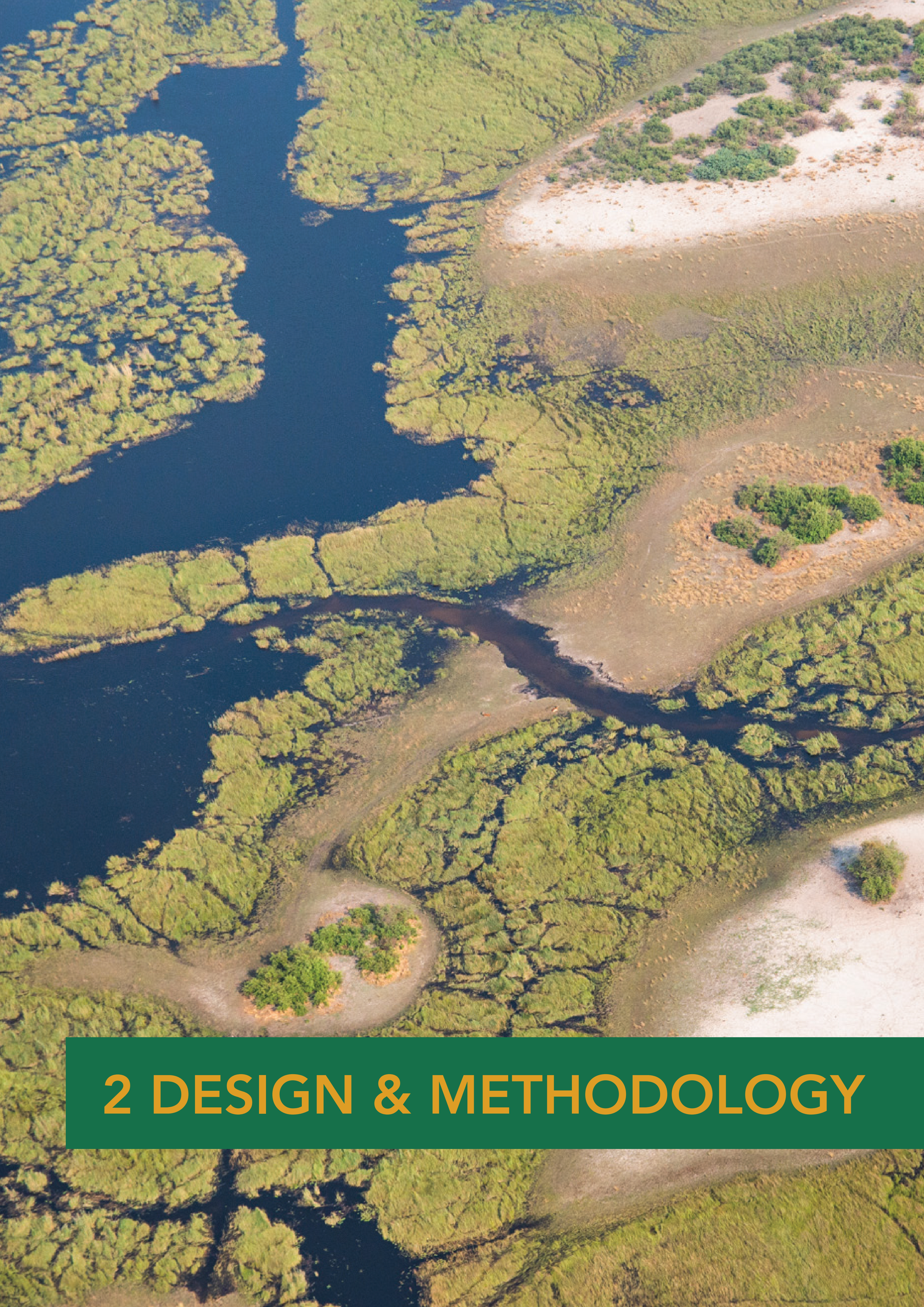
In April 2022, the process of procuring all the necessary equipment for the survey began. To ensure standardisation, the survey aircraft and crews were equipped with the same high-quality equipment sourced from various suppliers in the region and internationally, including laser altimeters, digital cameras, GPSs, and computers.

In May 2022, two suitable contractors demonstrating adequate experience in aerial wildlife surveying were identified through a public tender process to provide aircraft and crews to participate in the survey. The process of acquiring flight permits in the five partner countries was also initiated. Fuel quantities for the survey were calculated and purchased for distribution to the operational bases.

To promote standardised competencies of the observers, particularly the rear-seat observers from the five Partner States, a training and evaluation workshop was conducted from 20-26 July 2022. The selected personnel were subsequently seconded to the project by the Partner States for the duration of the survey. As a result of their contributions, the Partner States' personnel made up over 50% of the 47-person field team that comprised contractors, survey biologists, observers, and data managers. A presentation of the workshop is provided in Appendix 1.

On 15 August 2022, the Aerial Survey Manual and Standards were finalised, providing step-by-step technical procedures to be followed to ensure consistency and compliance with CITES MIKE Aerial Survey Standards Version 3.0 (CITES Secretariat, 2020). On 18 August 2022, an operations room was established at the Kasane Wildlife Office, providing a real-time view of field operations, and enabling support, coordination, and data quality assurance. On 22 August 2022 the survey officially commenced.

2 DESIGN & METHODOLOGY



2. Survey design and methodology

The survey design was based on the report produced as an output from the 2019 Survey Design Workshop (Dunham, 2020b). To ensure that all parts of the KAZA TFCA are surveyed in a standardised manner the methods employed throughout are those prescribed in the CITES MIKE Aerial Survey Standards Version 3.0 (CITES Secretariat, 2020), and detailed in the KAZA Elephant Survey Manual and Standards (Bussière, 2022a).

2.1 Survey area

The KAZA TFCA, spans a total of 519,912 km^2, of which 60% (310,865 km^2) was surveyed (Fig. 2.1). This portion of the KAZA TFCA is hereafter referred to as the survey area. The survey area was defined based on the survey design report of Dunham (2020b), which divided the area into three zones using data from previous surveys. These were a priority zone, where the elephant density was expected to be greater than 0.1 km^{-2}, a "to-be-determined" zone where the expected elephant density was less than 0.1 km^{-2}, and an excluded zone with no elephants expected. Surveying the entire "to-be-determined" zone was not feasible due to its large area (68% of the KAZA TFCA) and low expected elephant density which was anticipated to contain <10% of the total KAZA TFCA elephant population. Therefore, expert opinions and telemetry data[1] were consulted to identify locations within this zone with a high likelihood of elephant presence. Furthermore, areas with low elephant density or no elephants (based on other data) but deemed to have conservation significance were also considered.

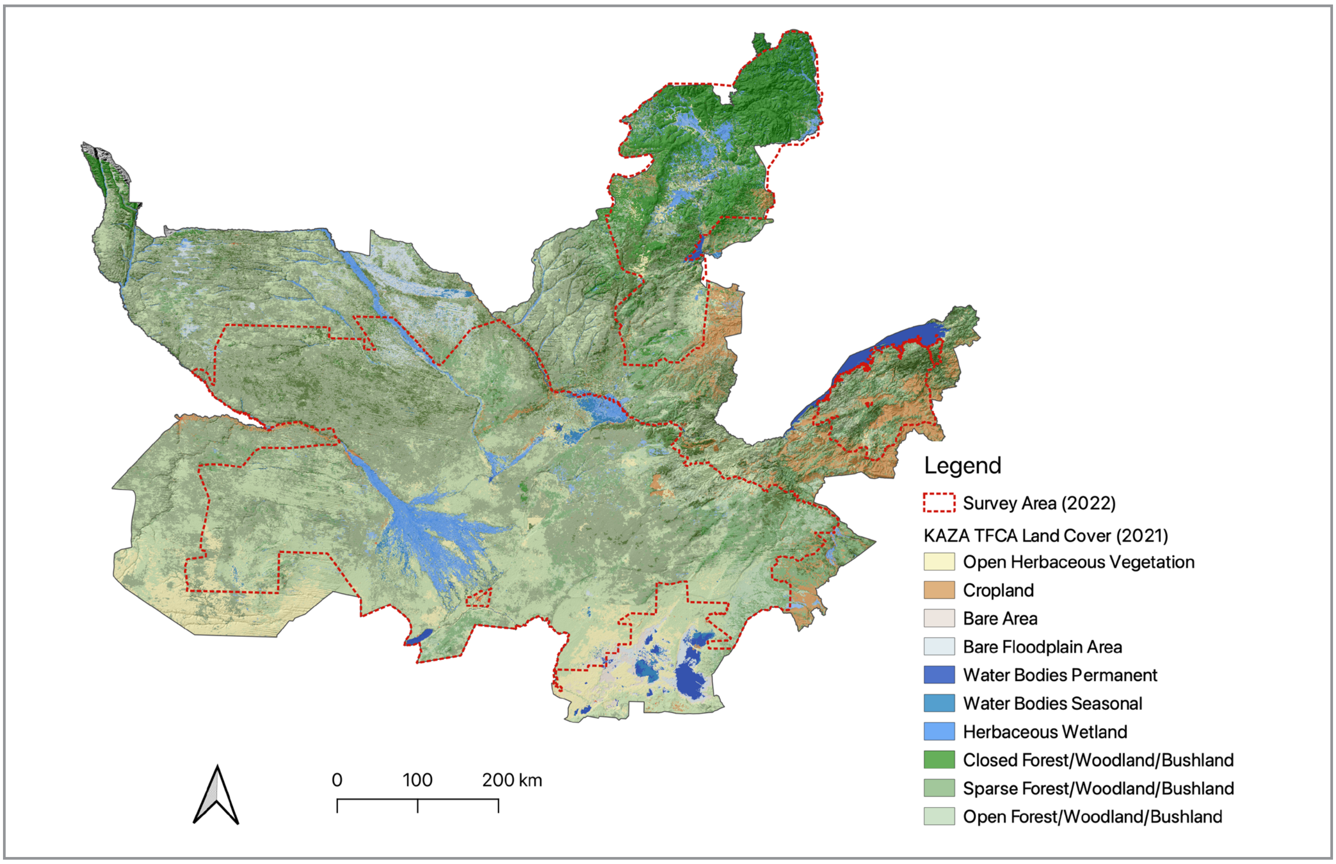


Figure 2.1: Land cover of the KAZA TFCA (produced by EOSS in collaboration with WWF (Gebhardt., 2021), and relief is provided by the 30-metre SRTM elevation data from the NASA Earthdata server (Duester, n.d.).

[1] *Approximately 92% of all collared elephant (n=291) locations fell within the survey area, supporting the expectation it should cover most of the elephant range found within the KAZA TFCA. This data set spans 10 years (KAZA Elephant Sub Working Group, unpublished data).*

2.2 Sampling methodology

Systematic transect sampling (Norton-Griffiths, 1978) was used for most of the KAZA TFCA, while stratified block sampling (Gasaway et al., 1986) was employed in two strata in the Sebungwe superstratum of Zimbabwe due to the rugged topography. This sampling approach is consistent with other recent surveys, including the 2014-15 Great Elephant Census (GEC) (Chase et al., 2016, 2018; Chase & Schlossberg, 2016, Craig et al., 2019, Dunham et al., 2015a, 2015b, Dunham, 2020a; DNPW, 2019, 2021).

2.3 Stratification

The survey area was partitioned into 179 strata of varying shapes and sizes, with an average area of 1729,4 km^2 (range: 83,7 km^2 – 5416,7 km^2) (Fig. 2.2). Although most stratum boundaries from previous surveys were preserved, the KAZA Elephant Survey (2022) revised the design of some strata, particularly in the transboundary area between Botswana and Namibia, where the international border is a river and substantial wildlife movement may occur. Although the border between Botswana and Zimbabwe also sees considerable transboundary movement of elephants, the strata in this region were not modified to span the frontier since it is not formed by a major ecological feature. Instead, to address the issue of transboundary elephant movement here, flights were conducted within a narrow timeframe on either side of the border (see Fig. 2.6)

Each stratum was assigned a unique name and code and grouped into eight "superstrata", each of which is an assembly of contiguous strata within a country. This stratification allowed for the application of different sampling intensities based on the expected density of elephants in each stratum and the adaptation of the sampling method to the terrain. Furthermore, it allowed for separate nested estimates for each stratum, superstratum, country, and for the entire KAZA TFCA survey area.

An additional 180th stratum (LCW) was included to provide a reliable estimate of red lechwe on the Busanga plains in Kafue National Park, Zambia[2], but the data collected here was not used for estimates for other species.

The baseline for the strata surveyed using transect sampling was computed using the geosphere package in R software (Hijmans R, 2022, R Core Team, 2022) as outlined in Appendix 2.

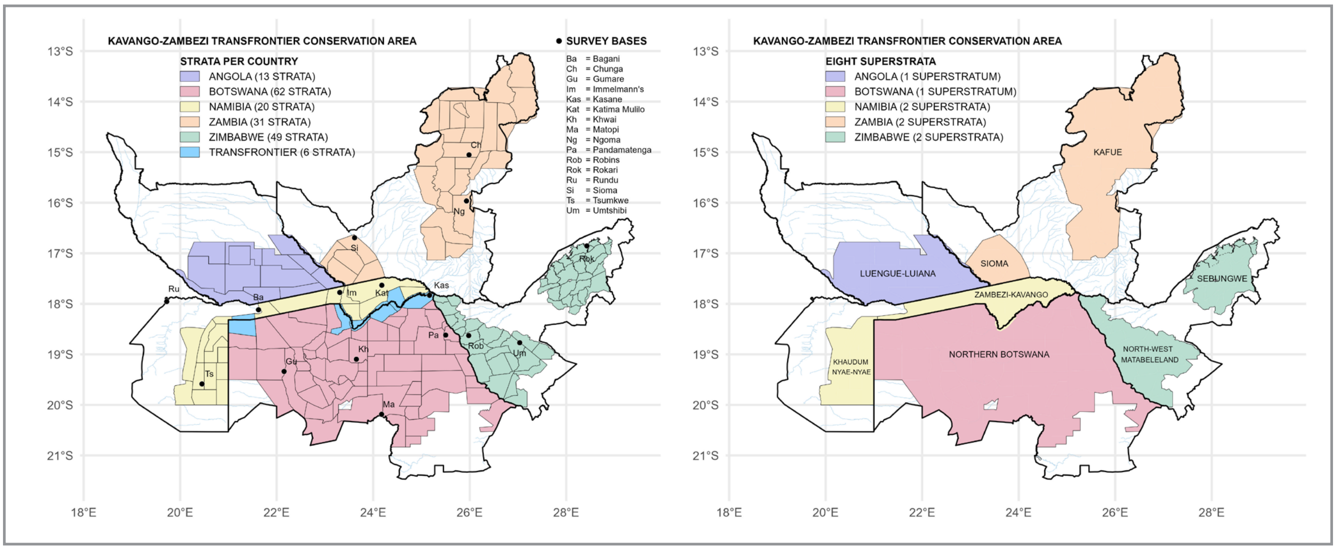


Figure 2.2: Stratification. Left: stratification showing 180 strata distributed amongst the five partner states, including six transboundary strata. Survey bases are also indicated.; Right: grouping of strata into eight labelled superstrata among the five Partner States

[2] LCW was considered and added since it required a relatively small amount of additional flying to provide a more reliable estimate for red lechwe in Kafue. This method has been used in previous surveys and thus gives comparable results. Additionally, it provided a wealth of imagery for the benefit of the Modernising Wildlife Surveys (MWS) project.

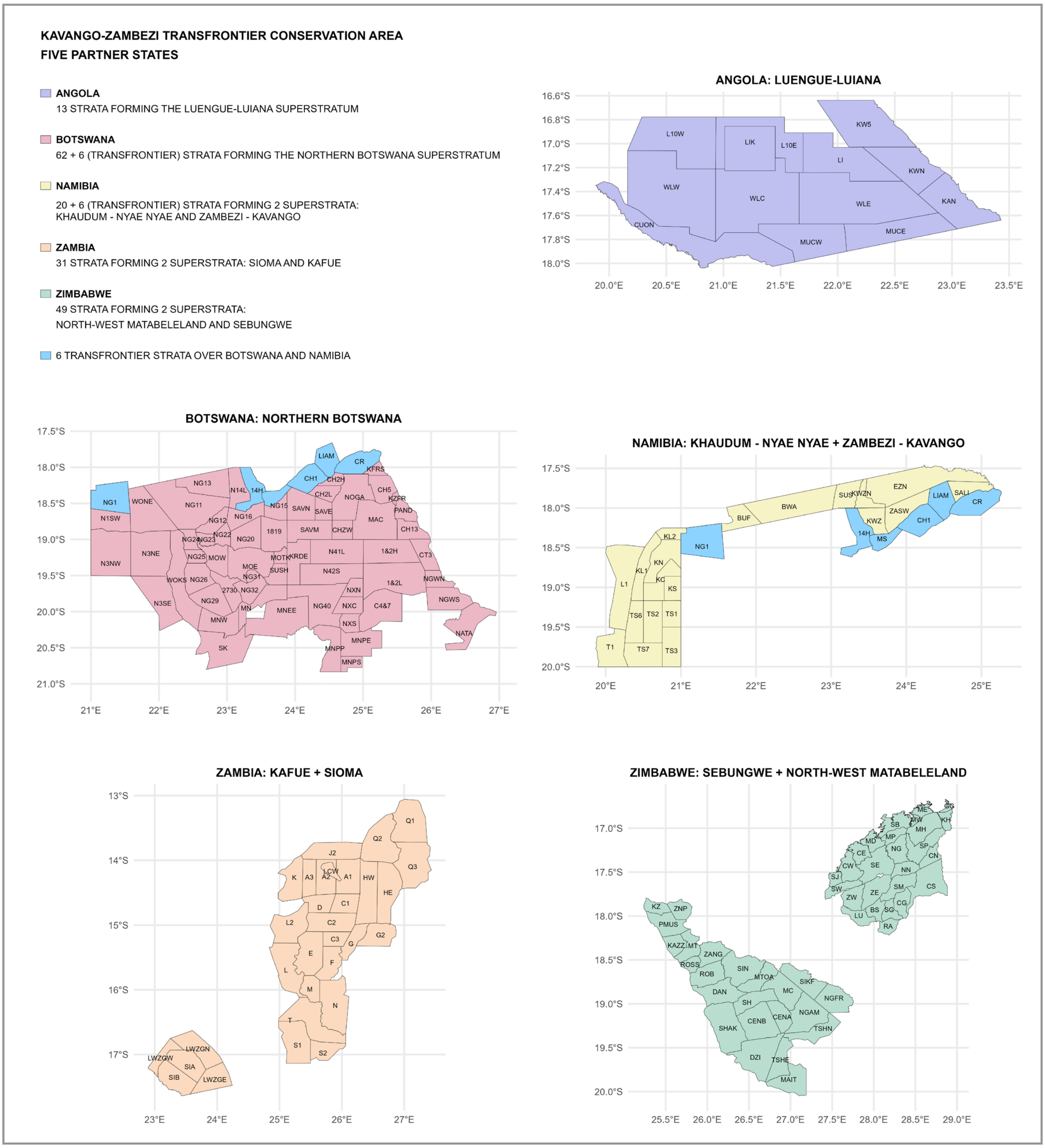


Figure 2.3: Detail of each stratum per country for all 180 strata in each of the five Partner States.

2.4 Sampling intensity

An aim of this survey was to produce an estimate for the number of elephants in the KAZA TFCA which has a 95 % confidence interval that is less than 10 % of that estimate. This precision target directly influences the selected overall sampling intensity. To achieve this level of precision, the appropriate overall mean sampling intensity was determined through simulation of predicted 95% confidence intervals for different sampling intensities (Dunham, 2020b). The results of this analysis determined that an overall mean sampling intensity of 6,5%, in the area where expected elephant density is greater or equal to 0.1 km^{-2}, would achieve the desired precision target. Additional flying was also planned to cover parts of those areas where elephant density was expected to be less than 0.1 km^{-2}, bringing the overall sampling intensity for the KAZA TFCA to nearly 7%. The allocation of sampling intensity to strata was optimised where prior information on the variability of elephant density was available, as described in the KES Manual and Standards (Bussière, 2022a).

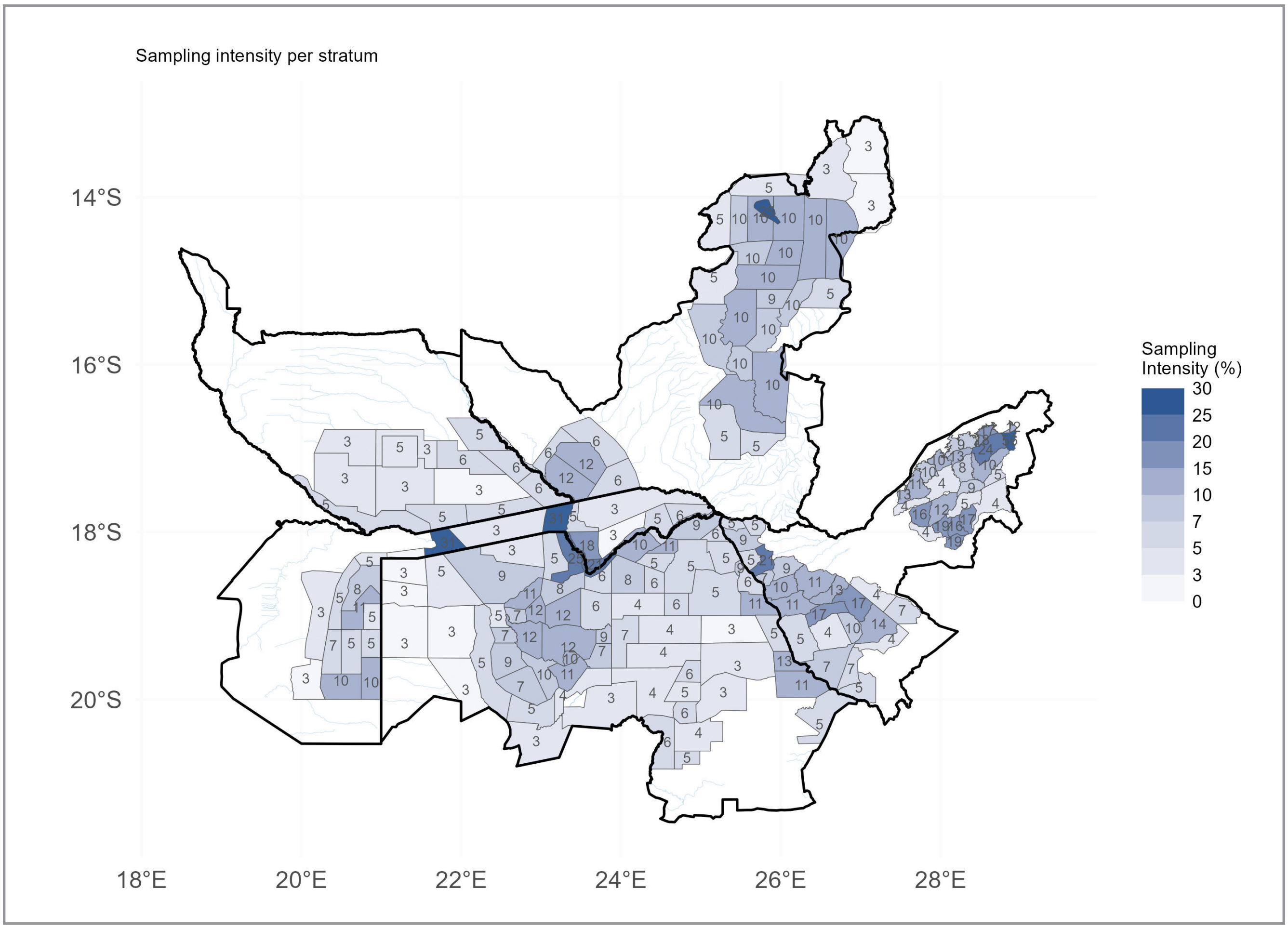


Figure 2.4: Sampling intensity across the 180 strata. The label shown in each stratum is the sampling intensity (% area) for that stratum.

2.5 Standards

In adherence to the CITES MIKE Aerial Survey Standards Version 3.0 (CITES Secretariat, 2020) a detailed step-by-step process was outlined and compiled in the KES Manual and Standards (Bussière, 2022a). This was done prior to the launch of the survey to provide a set of best practices that promote efficient and optimal work among the various teams involved. All those responsible for the planning and execution of the survey have endeavoured to follow the methods and practices as closely as possible (Table 2.1).

2.6 Target species

Elephants were the primary focus of the survey, and both live elephants and elephant carcasses were recorded. Live elephants were recorded separately as elephant families (i.e., breeding herds) or elephant bulls. Elephant carcasses were recorded and classified according to the four categories defined by Douglas-Hamilton and Hillman (1981). Furthermore, all large herbivores (>15kgs), both wild and domestic, were recorded. In order not to overburden observers in high animal density strata and reduce their focus on priority species, there was no requirement to record human activities (such as houses and crops), especially since the spatial distribution of these non-mobile indicators can be more thoroughly determined using other methods (e.g., satellite imagery). During survey flights, observers were required to take photographs of 1) large herds (>9 individuals) to ensure that herd sizes were accurately estimated, and of 2) elephant carcasses to ensure that category identification was correct.

Table 2.1: Summary of standards, in compliance with the CITES MIKE Aerial Survey Standards Version 3.0, applied during the KAZA Elephant Survey (2022).

Methodology	Sampling technique	Transect sampling (Norton-Griffiths, 1978) Block sampling for rugged terrain (Gasaway et al., 1986)
Timing and fatigue	Survey period Maximum flight time per transect Total flight time Rest days	Dry season months – leafless trees 20-25 mins 3.5h per flight and 5h per day max Morning and afternoon flights Rest day every 4 days (some flexibility)
Target parameters	Height AGL (transect) Height AGL (block) Ground speed (transect) Ground speed (block) Observer strip width Search rate Search effort	91 m (300 ft) ± 9.1 m (30 ft) SD 15-213 m (50-700 ft). 170 $km.h^{-1}$ (105 mph, 92 knots) ± 10 $km.h^{-1}$ (6 mph, 5 knots) SD; < 185 $km.h^{-1}$ (115 mph, 100 knots) ≤ 140 $km.h^{-1}$ (87 mph, 75 knots) 150 m ± 15 m (either side) 0.85 (≤1) $km^2.min^{-1}$ 1.17 (≥1) $min.km^{-2}$

2.7 Coordination

To ensure efficient coordination, an operations room was established within the Department of Wildlife and National Parks Kasane Wildlife Office in Botswana and staffed with six data analysts seconded to the project by the partner states. The room was equipped with the EarthRanger cloud-based domain awareness system, which enabled real-time monitoring of the survey operations using Garmin InReach satellite communication devices placed in each aircraft. These devices transmitted GPS position data every two minutes, allowing the operations room to monitor safety, support the crews, and ensure data quality. By centralising all the information, the operations room became an indispensable tool for the successful coordination and implementation of the survey. The functioning of the operations room is detailed in Appendix 3.

The coordinating team also facilitated the Modernising Wildlife Surveys (MWS) research initiative during the survey. This project involves the utilisation of high-resolution cameras to develop more modernised and robust approaches to aerial surveying of wildlife, which are not subject to the inherent limitations associated with observer bias. To this end, five aircraft were fitted with high-resolution oblique camera systems either clamped on the wing struts or mounted inside the cabin where they replaced the traditional rear seat observer cameras.

The coordinating team was responsible for managing all the logistical aspects of the survey, from the acquisition of flight permits to the procurement and distribution of fuel. Details of this undertaking and the challenges encountered are available in Appendix 4.

2.8 Survey implementation

The survey was conducted at the height of the dry season when most deciduous trees are leafless and visibility is highest, and before the onset of the rainy season. A total of 195 survey flights were made between 22 August and 28 October 2022, by nine crews, flown from sixteen bases located throughout the KAZA TFCA as shown in Fig. 2.5. In addition, three reconnaissance flights were conducted to search for elephants in likely habitat. These were carried out north of Sioma in Zambia, in the Fuller Forest area south of Victoria Falls in Zimbabwe, and along the Boteti River near Rakops, in the Central district of Botswana (refer to Appendix 5). An additional transect survey flight was conducted in Kafue National Park, Zambia to provide a reliable population estimate for red lechwe in the Busanga plains.

During the survey, most strata were covered in a single flight session. However, there were some large strata that required multiple flight sessions to complete, which are referred to as "multi-flight strata." This means that either two aircraft and their crews surveyed different portions of the same stratum, or a single aircraft and crew conducted the survey over several flight sessions to cover the entire stratum. On the other hand, when dealing with smaller strata, it was possible for a single aircraft and its crew to survey more than one stratum in a single flight session (i.e., from take-off to landing), referred to as a "multi-strata flight."

Pre-survey observer calibration exercises were carried out for crews conducting systematic transect sampling. Some crews also collected peri-survey calibration data (i.e., during the survey, for example two calibration passes prior to commencing a survey flight). Refresher flights were conducted in conditions identical to those required during the survey, giving crews the opportunity to activate their procedural memory. By taking the time to prepare beforehand, crew members were able to commence at a high level of performance from the start of the first survey flights. Details of the data collection protocols and procedures are available in the KES Manual and Standards (Bussière, 2022a).

Table 2.2: Survey period in each country.

Country	Start Date	End Date	Elapsed days
Angola	2022/10/18	2022/10/24	7
Botswana	2022/09/10	2022/10/11	32
Namibia	2022/10/01	2022/10/15	15
Zambia	2022/08/26	2022/10/28	64
Zimbabwe	2022/08/22	2022/09/09	19

Table 2.3: Survey period and crews in each superstratum.

Superstratum	Start Date	End Date	Elapsed days	Crew
Luengue-Luiana	2022/10/18	2022/10/24	7	C01 – C02 – C04
North-West Matabeleland	2022/08/30	2022/09/09	11	C01 – C02 – C03
Kavango Zambezi	2022/10/01	2022/10/10	10	C01 – C02 – C03 – C04
Northern Botswana	2022/09/10	2022/10/11	32	C01 – C02 – C03 – C04
Khaudum Nyae-Nyae	2022/10/11	2022/10/15	5	C01 – C02 – C04
Kafue	2022/08/26	2022/09/22	28	C05 – C07
Sioma	2022/10/03	2022/10/28	26	C06 – C07
Sebungwe	2022/08/22	2022/09/09	19	C08 – C09

A series of maps showing the strata sampled by each crew, and a table summarising the efforts made by each crew, are available in Appendix 6. A detailed crew calendar is provided in Appendix 7.

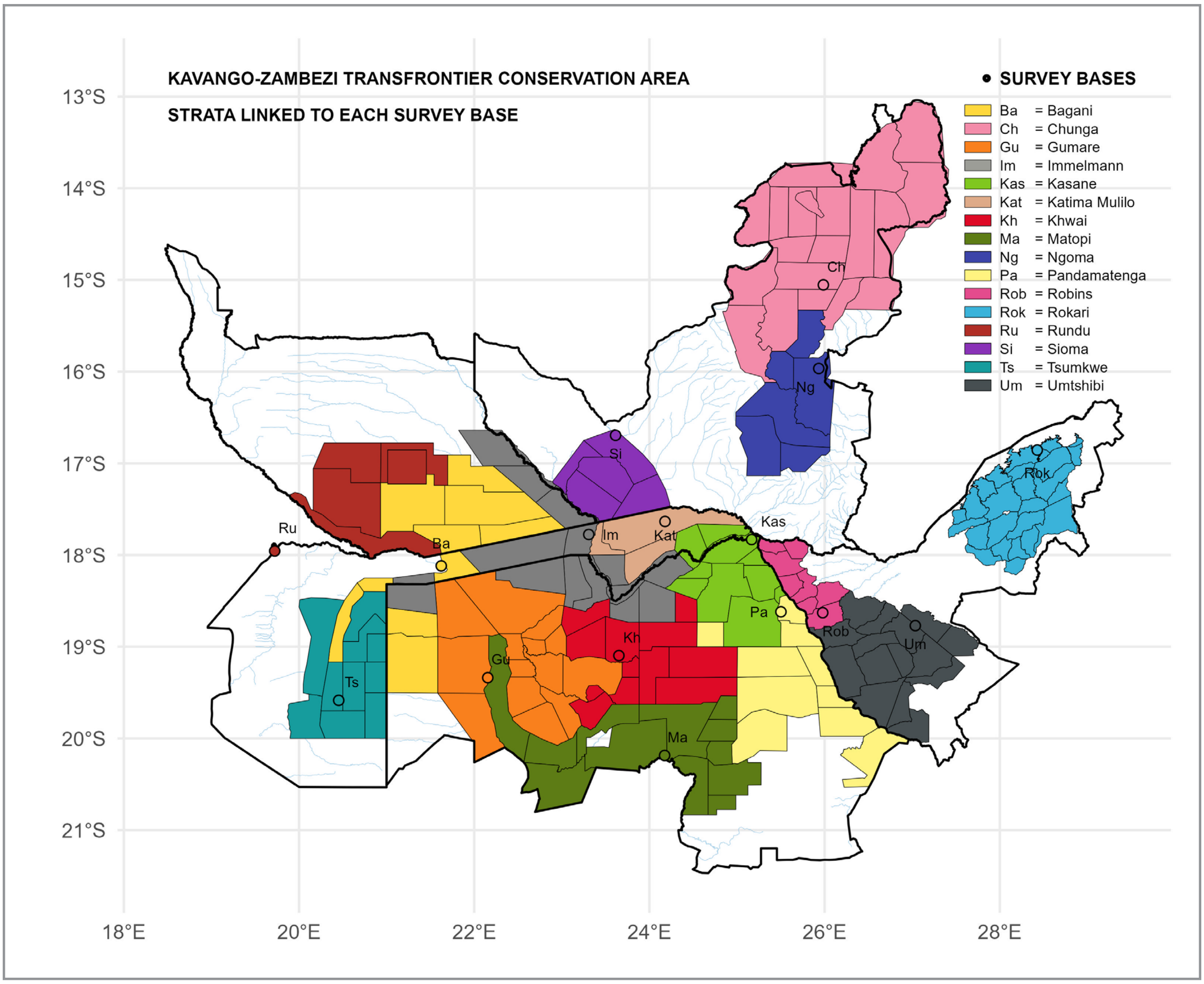


Figure 2.5: Allocation of strata to each of the 16 survey bases.

A series of maps showing the weekly progress of the sampling effort is available in Appendix 8. A list of the characteristics of the aircraft and technological devices used in the survey is available in Appendix 9, while a detailed presentation of the personnel is available in Appendix 10.

Table 2.4: Survey bases and associated details.

Survey base	Country	Longitude	Latitude	Ave. dist. centroids	Elapsed days	Start Date	End Date	No of Strata	No of Flights	Fuel used	Tot Flt. time	Tot Tr. time	Tot Tr. length
Bagani	Namibia	21.62330	-18.11848	89	14	2022/10/10	2022/10/23	10	12	2000	38	23	3981
Chunga*	Zambia	25.98567	-15.05396	94	21	2022/08/26	2022/09/15	19	30	7000	126	68	11748
Gumare	Botswana	22.15440	-19.33800	78	6	2022/09/20	2022/09/25	14	18	3200	61	38	6493
Immelmann	Namibia	23.30758	-17.77604	92	22	2022/10/03	2022/10/24	14	19	3400	63	37	6383
Kasane**	Botswana	25.16640	-17.83147	64	22	2022/09/10	2022/10/01	10	6	1300	25	16	2689
Katima Mulilo	Namibia	24.17789	-17.63405	56	1	2022/10/02	2022/10/02	3	3	420	8	4	751
Khwai	Botswana	23.65156	-19.09664	61	5	2022/09/26	2022/09/30	12	9	1800	35	22	3775
Matopi*	Botswana	24.17359	-20.18584	93	4	2022/09/16	2022/09/19	12	10	2000	37	21	3646
Ngoma	Zambia	25.93330	-15.96580	76	7	2022/09/16	2022/09/22	6	11	2400	42	26	4358
Pandamatenga	Botswana	25.50140	-18.61956	101	6	2022/09/10	2022/09/15	10	11	2000	38	20	3446
Robins	Zimbabwe	25.97840	-18.62933	50	2	2022/09/08	2022/09/09	8	5	1200	21	10	1656
Rokari*	Zimbabwe	28.42792	-16.85525	79	19	2022/08/22	2022/09/09	26	18	1600	64	34	4626
Rundu	Namibia	19.72201	-17.95606	148	4	2022/10/19	2022/10/22	5	7	1200	22	11	1870
Sioma*	Zambia	23.61346	-16.69431	63	26	2022/10/03	2022/10/28	5	8	1600	29	17	2887
Tsumkwe	Namibia	20.45280	-19.58500	56	3	2022/10/13	2022/10/15	10	10	1600	32	19	3308
Umtshibi*	Zimbabwe	27.03545	-18.77037	66	8	2022/08/30	2022/09/06	15	18	2600	53	31	5385

This table provides for each survey base: the country in which it is located and its GPS coordinates, its average distance (kilometres) to the centroids of all strata surveyed from this base, the number of days in use and the corresponding start and end dates, the number of surveyed strata and the number of executed flights (red lechwe flight excluded). It also provides fuel used (litres), the number of survey hours flown, total transect hours flown, and total transect length (kilometres)
*The survey bases where calibration exercises have taken place.
**Kasane was used as a base, but calibration took place over the nearby Impalila airstrip.

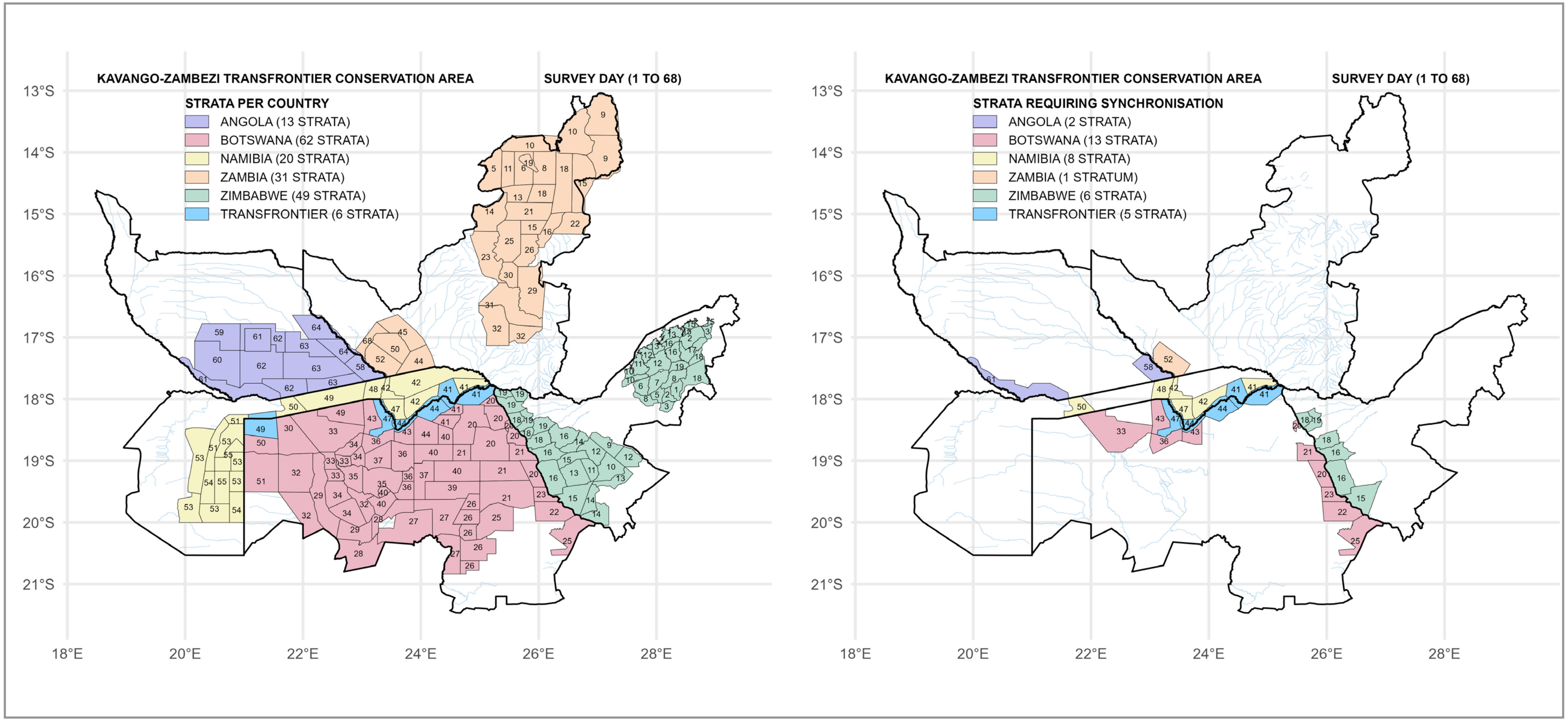


Figure 2.6: Flying calendar. Left: Survey Day ranging from 1 (22-08-2022) to 68 (28-10-2022), for each of the 180 strata and Right: for the 30 strata requiring synchronisation due to potentially important cross-border elephant movement.

2.9 Data curation

The storage of observation and flight data was organised by flight, each with a unique identifier. This primary database was then reorganised by stratum to allow analysis at stratum level. Thus, data collected during several flights within the same stratum (multi-flight stratum) were aggregated. Conversely, datasets collected over several strata during a single flight (multi-strata flight) were split for analysis. The output files of the data analysis were then compiled for the whole KAZA TFCA region, producing two files: the transect and flight performance file and the observation file.

2.10 Data analysis

The data collected in preparation for and during the execution of the survey can be separated into three sets: calibration, flight, and observation data.

2.10.1 Calibration data analysis

Calibration data were analysed differently depending on whether they were collected in pre-survey calibration exercises, or peri-survey calibration passes.

2.10.1.1 Pre-survey calibration data

Data collected before the survey launch was analysed in-field to validate the collection protocol and establish the proportionality relationship between flight height and search strip width. This was done through simple linear regression analysis and intercept-free linear regression analysis, calculating the search strip width value at 300 ft (91 m).

For each calibration session (a series of about twenty overflights over the marked airstrip) a simple linear regression model ($y = ax + b$) was fitted to the data collected by the left observer, the right observer and finally to the combined data. The slope and the intercept were calculated to define the relationship between the flight height x and the search strip width y, as well as the coefficient of determination r^2 to determine how well the regression model fits the data. The search strip width was expected to be positively and linearly correlated with the flying height, close to 150 m (one-side) or to 300 m (combined) at 300 feet, with a coefficient of determination r^2 as close to 1 as possible, and a y-intercept as close to zero as possible. The standard error of the mean calibrated strip width was also calculated and expected to be less than 5% of the mean calibrated strip width. To do this, the search strip width (w_i) calculated for each pass i and associated flight height h_i, was cross-multiplied to obtain the proportional value, at a flight height h_{300} of 300 feet ($w_{300} = h_{300} \cdot \frac{w_i}{h_i}$). The standard error and relative standard error (RSE) of this new sampling distribution were calculated.

$RSE = \frac{SE}{\overline{w_{300}}}$ with $\overline{w_{300}} = \frac{\sum_i w_{300i}}{n_i}$, n_i, being the total number of passes.

When the results of the simple linear regression analysis were satisfactory, the calibration exercise was validated, and an intercept-free linear regression model was fitted to the data ($y = ax$). The forced slope was calculated to define the proportional relationship between the flight height (x) and the search strip width (y). This relationship, specific to each pair of rear seat observers, was then used to estimate the average search strip width for each of the 2404 transects (+35 with LCW, see Fig. 2.3) as a function of the average flight height along the transect.

2.10.1.2 Peri-survey calibration data

The peri-survey data were analysed after the survey, separately and combined with the pre-survey data. The results of the simple linear regression analysis obtained for the pre- and peri-survey calibration datasets were compared, to assess the validity of the following hypothesis: the data collection protocols during the initial calibration and during the survey are identical and the search strip width estimate remains unchanged.

With the intention of assessing the impact of potential variability of the strip width estimate, for each pair of observers whose total number of passes was greater than 25 (all sessions, pre- and peri-survey data combined), a bootstrapping exercise (random sampling with replacement) was carried out to create several simulated samples, from which new proportional relationships between the flight height (x) and the search strip width (y) were calculated, using the same linear regression analysis approach. This resulted in a range of possible forced slope values used, in addition to the selected value, to explore the impact that this variability might have on the elephant population estimates.

2.10.2 Flight data analysis

Flying speed and height data were recorded by the laser altimeter and saved to a GPX file after each flight. By using the start and end time of the transect recorded by the front seat observer, it was possible to restrict each GPX file to the data recorded during the transect only. The sampling intensity and search effort were calculated for each stratum, whereas the mean and standard deviation for speed and height were calculated for each transect to assess adherence to flight standards. The data were summarised in graphics that were used daily by crews to validate flights, provide feedback to teams, and continuously optimise flight performance.

The percentage of transects for which the pilot adheres to the flight standards was calculated for each pilot. In addition, several analyses of variance (ANOVA) of height and ground speed against several categorical variables were performed to determine whether there were any statistically significant differences between pilots, aircraft, strata, flight and transect number (from 1 for the first transect of the flight, to n for the last one).

The average flight height was also used to estimate the average search strip width of each transect and thus the sampling area in each stratum. This was also done for the range of possible forced slope values obtained by the bootstrapping exercise, to reflect the variability of the strip width estimate on the sampling area estimate.

In the event of a laser altimeter malfunction and data loss, speed information was derived from the GPS tracklog while height data came from recordings made by the front seat observer, at an interval of approximately thirty seconds, by direct reading of the laser altimeter measurement display, throughout the flight. For four flights where no flight height data were available, this information was derived from the altitude data recorded by the aircraft's GPS and the 30-metre NASA Shuttle Radar Topography Mission (SRTM) data (i.e., elevation data).

2.10.3 Observation data analysis

The observation data consists of a standardised dataset for the 38 target species of large herbivores, with observations recorded both within and outside the search strip. The crews had discretion to record observations for species other than the target species and while off transect, but only data collected for the target species within the search strip while on transect was used to calculate population estimates. All the observation data, including data collected outside the search strip and while off transect, were used to produce distribution maps.

2.10.3.1 Stratum level analysis

For systematic transect sampling the Jolly's (1969) method 2 for unequal sized sampling units was used to calculate, for each stratum and each species, the population estimate, its variance, and its confidence limits. For block sampling the Jolly's (1969) method 3 was used to calculate, for each stratum and each species, the population estimate, its variance, and its confidence limits.

For the four multi-flight strata sampled repeatedly with interleaved flights executed at different times, due to the possibility of counting some individuals several times during repeat flights, the stratum population estimates from each flight were averaged, the variances were summed and divided by the number of replicates squared (*sensu* Craig et al., 2019), and the 95% confidence limits were calculated using Satterthwaite's (1946) approximation for degrees of freedom (in Gasaway et al., 1986).

For live elephants only (breeding herd and bulls), these analyses were also performed using the minimum and maximum possible sampled area values, to assess the influence of potential variability in the search strip width estimate on the population estimate.

2.10.3.2 Landscape level analysis

To estimate populations of larger areas, the population estimates and variances of individual strata were summed, and the 95% confidence limits were calculated using Satterthwaite's (1946) approximation for degrees of freedom, as outlined in Gasaway et al. (1986).

The selection of strata for the landscape level analysis was contingent upon the specific scale required. For population estimates of the entire KAZA TFCA survey area, we included all 179 strata. For specific portions of the KAZA TFCA within each country, we limited the analysis to the relevant strata within each country. Similarly, for superstrata analysis, we only considered strata within each designated superstratum.

Due to the design of six transboundary strata (i.e., 14H, CH1, CR, LIAM, MS, and NG1), it was not possible to obtain results for the Namibian and Botswana portions of KAZA TFCA, as well as the Kavango-Zambezi superstratum in Namibia. To address this, these six strata and their associated datasets were post-processed to be spatially partitioned into two along the Namibia-Botswana border (i.e., 14H was split into 14HNA and 14HBW etc.).

2.10.3.3 The special case of red lechwe on the Busanga Plains

In the Kafue ecosystem, the red lechwe is almost exclusively found on the Busanga plains, with a highly localised distribution. To obtain a more accurate population estimate for this species, a new stratum called "LCW" was specially designated to encompass this specific habitat. This stratum was defined after the survey of the overlying strata A1 and A2, which allowed for an accurate delineation of the red lechwe's range. Incorporating the LCW stratum in the red lechwe data analysis necessitated excluding data for this species obtained from the overlying strata (A1 and A2). This focused approach ensures that the population estimate for red lechwe in the Busanga plains is more accurate and reflective of its concentrated distribution in that habitat.

2.10.4 Carcass ratios

Using the population estimates calculated for live elephants and elephant carcasses, the carcass ratio (Douglas-Hamilton & Burrill, 1991) was derived for carcasses in all categories, as well as for categories 1-2 together, at stratum, superstratum, country and KAZA TFCA survey area level. The all-carcass ratio (CR14) is expressed as a percentage of the number of dead elephants (of all carcass categories) divided by the number of dead (all carcass categories) plus live elephants. It provides an index of elephant mortality in the several years prior to the survey. The fresh and recent carcass ratio (CR12) is derived in the same way but using the estimates of only the fresh and recent carcasses (categories 1 and 2), and provides an index of recent mortality, in the year leading up to the survey. Carcass ratios can offer additional insight into changes in population numbers across consecutive surveys.

2.10.5 Observer performance

For each pair of observers and for each species/carcass category, a chi-square test was used to compare the number of observations made on the left and right side, while taking into consideration the difference in width of the respective search strips. For each pair of observers and for each common gregarious species (group size > 3 and number of observations > 5), a Mann-Whitney U test was used to compare left- and right-side group sizes.

2.10.6 Distribution and density maps

For each species and carcass category a series of maps was produced, representing:

- distribution (dot map)
- distribution and herd size (graduated dot map)
- density by stratum (choropleth map[3])
- distribution and density by stratum (dot and choropleth map)

An elephant-specific distribution map was produced by overlaying the distribution of family herds, bulls, carcass categories 1-2 and carcass categories 3-4.

To show the distribution of elephants in relation to a measure of human pressure, a map was produced overlaying the observations of live elephants (bulls and family herds) and cattle on a human settlement density map created from the Open Buildings dataset[4] (Sirko et al, 2021).

Using calculated population estimates, the relative abundance between wild and domestic animals was calculated in each stratum and illustrated through a choropleth map.

Additional choropleth maps were produced to illustrate at stratum level the two carcass ratios, the sampling intensity, and the percentage of relative precision for elephants (PRP). Moreover, additional maps of the two carcass ratios are included, where the data is filtered to show only the carcass ratios for strata where at least 30 live elephants were estimated. The purpose of this filtering is to offer a more focused understanding where mortality rates are relatively high, rather than being the result of the absence of live elephants.

2.10.7 Photo interpretation

To establish a benchmark for future surveys, descriptive statistics were calculated to gain insights into the photo interpretation process used during the survey. This included determining the percentage of required photos that were successfully collected and used to verify the accuracy of observed herd sizes and validate the identified carcass categories. Additionally, the percentage of observations that required correction after matching photos was calculated, to provide insight into the impact that photo interpretation can have on the accuracy of the data. Finally, the amplitude of correction according to herd size is quantified and presented in a bar chart.

[3] In a choropleth map each polygon is coloured or shaded based on the value of a particular variable or data attribute associated with that area. The intensity or darkness of the colour or shading corresponds to the magnitude or concentration of the data in that polygon.
[4] The Open Buildings data was used to produce a building density map that shows the percentage of building footprint in a 1km^2 grid.

3 RESULTS

3. Results

3.1 Population estimates and distribution

The survey enables the generation of population estimates and distribution maps at four scales, namely at the level of: the whole KAZA TFCA survey area, each country[5], each superstratum, and for each stratum. These different geographical units are subsequently referred to as zones.

Table 3.1 to Table 3.17 summarise the population estimates for the first three scales, while the second volume to this report provides extensive results for each of the 179 strata, detailing the survey design, approach to implementation, data and statistics on observations of live elephants, elephant carcasses and other target species, and flight performance.

In section 3.1.1, the report presents population estimates for elephants and elephant carcasses across all zones, accompanied by distribution and density maps. Section 3.1.2 contains results for all species, including repeated data on elephants and elephant carcasses in each zone. The assessment acknowledges that detecting certain herbivore species from the air is challenging, likely resulting in underestimated population numbers. Nevertheless, population estimates are included as valuable abundance indices with precision measures, and since repeated surveys can reveal temporal trends in population size. Additionally, distribution and density maps are available for other species. However, it is important to note that the colour gradient in density maps is specific to each species' density values, precluding direct comparison between species or carcass categories. The distribution maps presented are based on observations from both inside and outside the search strip, as well as reconnaissance flights.

In the tables, elephants are placed first, followed by wildlife and livestock, in alphabetical order. The meaning of column headings, from left to right:

- **Zone:** is the area for which the estimate is given, this can be for the entire survey area, country (i.e., the KAZA TFCA portion in that country), superstratum, or stratum.
- **Species:** is the species or carcass category for which the estimates have been derived.
- **Population Estimate ($\hat{Y}$):** is the estimated population for that species (or carcass category) in that zone.
- **CI:** is the 95% confidence interval of the population estimate for that species in the zone.
- **Lower CL:** the lower limit of the range of the 95 % confidence interval of an estimate.
- **Upper CL:** the upper limit of the range of the 95 % confidence interval of an estimate.
- **PRP:** the Percentage Relative Precision is the CI expressed as a percentage of an estimate, and is a measure of precision for the estimate.
- **No Seen In:** the number of individuals seen inside the search strips or blocks during a survey.
- **No Seen Out:** the number of individuals seen outside the search strips or blocks during a survey (it includes individuals seen on turns and on transit to and from base).
- **Variance:** is the variance of the population estimate in that zone.

The confidence interval, lower and upper confidence limits, and percentage of relative precision essentially describe the same information in different ways and are all presented here for ease of reference.

[5] *The results presented at the country level only represent the surveyed portion of the KAZA TFCA within that country, not the entire country itself.*

For practical interpretation purposes, the population of a given species likely lies between the lower and upper confidence limits, with the 'estimate' representing the best approximation within that range. For instance, based on Table 3.1, one can say that there were between 29770 and 35348 elephant bulls in the KAZA TFCA survey area at the time of survey, with 32559 being the most probable estimate.

3.1.1 Elephant estimates and distribution

Population estimates are provided below for live elephants and elephant carcasses, which are then used to calculate carcass ratios. A series of maps, presented in Fig. 3.1 to Fig. 3.13 show the distribution and density of live elephants and elephant carcasses, as well as the carcass ratio throughout the survey area.

Table 3.1: Live elephant population estimates and associated statistics for the KAZA TFCA survey area, country, and each superstratum.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
KAZA	all elephants	227900	±16743	211157	-	244643	7%	23615	38877	0.733	72191578
	elephant bulls	32559	±2789	29770	-	35348	9%	3005	5384	0.105	2012566
	elephant family	195342	±16180	179162	-	211522	8%	20610	33493	0.628	67353691
Angola	all elephants	5983	±6461	355	-	12444	108%	355	633	0.165	9384212
	elephant bulls	303	±337	17	-	640	111%	17	29	0.008	27266
	elephant family	5679	±6466	338	-	12145	114%	338	604	0.156	9360772
Botswana	all elephants	131909	±11933	119976	-	143842	9%	11944	20875	1.067	36767969
	elephant bulls	21167	±2363	18804	-	23530	11%	1741	3280	0.171	1439801
	elephant family	110742	±11364	99378	-	122106	10%	10203	17595	0.895	33317299
Namibia	all elephants	21090	±3888	17202	-	24978	18%	3770	5325	0.580	3853056
	elephant bulls	3106	±796	2310	-	3902	26%	407	557	0.085	160151
	elephant family	17984	±3764	14220	-	21748	21%	3363	4768	0.495	3607901
Kavango Zambezi	all elephants	12345	±2519	9826	-	14864	20%	3008	4220	0.684	1611432
	elephant bulls	1069	±301	768	-	1370	28%	251	276	0.059	22941
	elephant family	11276	±2476	8800	-	13752	22%	2757	3944	0.624	1557452
Khaudum Nyae Nyae	all elephants	8745	±3009	5736	-	11754	34%	762	1105	0.478	2241625
	elephant bulls	2037	±741	1296	-	2778	36%	156	281	0.111	137210
	elephant family	6708	±2884	3824	-	9592	43%	606	824	0.366	2050449
Zambia	all elephants	3840	±1398	2442	-	5238	36%	385	475	0.052	492051
	elephant bulls	359	±162	197	-	521	45%	36	23	0.005	6611
	elephant family	3481	±1371	2110	-	4852	39%	349	452	0.047	471802
Kafue	all elephants	3840	±1398	2442	-	5238	36%	385	475	0.060	492051
	elephant bulls	359	±162	197	-	521	45%	36	23	0.006	6611
	elephant family	3481	±1371	2110	-	4852	39%	349	452	0.054	471802
Sioma*	all elephants	Not observed in the sample						0	0		
Zimbabwe	all elephants	65028	±9457	55571	-	74485	15%	7161	11569	1.599	21722971
	elephant bulls	7606	±1217	6389	-	8823	16%	804	1495	0.187	377077
	elephant family	57422	±9220	48202	-	66642	16%	6357	10074	1.412	20591615
North-West Matabeleland	all elephants	61531	±9408	52123	-	70939	15%	6643	11466	2.457	21459924
	elephant bulls	7155	±1195	5960	-	8350	17%	737	1482	0.286	363285
	elephant family	54376	±9173	45203	-	63549	17%	5906	9984	2.171	20346770
Sebungwe	all elephants	3498	±1020	2478	-	4518	29%	518	103	0.224	263046
	elephant bulls	451	±244	207	-	695	54%	67	13	0.029	13793
	elephant family	3046	±984	2062	-	4030	32%	451	90	0.195	244845

*Refer to Table 3.4 for the elephants counted during reconnaissance flights

Table 3.2: Elephant carcass estimates and associated statistics for the KAZA TFCA survey area, country, and each superstratum.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
KAZA	all elephant carcasses	26641	±1645	24996	-	28286	6%	2157	792	0.086	698728
	C1-2 elephant carcasses	1165	±290	875	-	1455	25%	104	34	0.004	20993
	C3-4 elephant carcasses	25476	±1595	23881	-	27071	6%	2053	758	0.082	656417
	elephant carcass one	277	±115	162	-	392	42%	29	14	0.001	3274
	elephant carcass two	888	±266	622	-	1154	30%	75	20	0.003	17388
	elephant carcass three	9753	±998	8755	-	10751	10%	780	307	0.031	256754
	elephant carcass four	15722	±1148	14574	-	16870	7%	1273	451	0.051	337767
Angola	all elephant carcasses	1163	±338	825	-	1501	29%	58	19	0.032	28880
	C1-2 elephant carcasses	34	±76	1	-	110	224%	1	2	0.001	1183
	C3-4 elephant carcasses	1129	±333	796	-	1462	29%	57	17	0.031	27975
	elephant carcass one							0	0		
	elephant carcass two	Not observed in the sample			-	110	224%	1	2	0.001	1183
	elephant carcass three	589	±272	317	-	861	46%	30	7	0.016	18340
	elephant carcass four	540	±226	314	-	766	42%	27	10	0.015	12857
Botswana	all elephant carcasses	19371	±1471	17900	-	20842	8%	1430	564	0.157	556989
	C1-2 elephant carcasses	962	±270	692	-	1232	28%	79	29	0.008	17924
	C3-4 elephant carcasses	18409	±1422	16987	-	19831	8%	1351	535	0.149	519720
	elephant carcass one	228	±105	123	-	333	46%	22	13	0.002	2696
	elephant carcass two	734	±250	484	-	984	34%	57	16	0.006	15075
	elephant carcass three	6417	±847	5570	-	7264	13%	489	188	0.052	183747
	elephant carcass four	11992	±1061	10931	-	13053	9%	862	347	0.097	286656
Namibia	all elephant carcasses	780	±251	529	-	1031	32%	104	12	0.021	14829
	C1-2 elephant carcasses	92	±57	35	-	149	62%	16	0	0.003	798
	C3-4 elephant carcasses	688	±246	442	-	934	36%	88	12	0.019	14014
	elephant carcass one	23	±27	4	-	50	117%	4	0	0.001	172
	elephant carcass two	69	±51	18	-	120	74%	12	0	0.002	631
	elephant carcass three	422	±230	192	-	652	55%	36	4	0.012	11688
	elephant carcass four	266	±100	166	-	366	38%	52	8	0.007	2534
Kavango Zambezi*	all elephant carcasses	595	±238	357	-	833	40%	89	11	0.033	12880
	C1-2 elephant carcasses	61	±46	15	-	107	75%	13	0	0.003	501
	C3-4 elephant carcasses	534	±235	299	-	769	44%	76	11	0.030	12328
	elephant carcass one	11	±12	3	-	23	109%	3	0	0.001	34
	elephant carcass two	50	±45	5	-	95	90%	10	0	0.003	472
	elephant carcass three	336	±224	112	-	560	67%	29	3	0.019	10696
	elephant carcass four	199	±83	116	-	282	42%	47	8	0.011	1675
Khaudum Nyae Nyae	all elephant carcasses	185	±89	96	-	274	48%	15	1	0.010	1949
	C1-2 elephant carcasses	32	±35	3	-	67	109%	3	0	0.002	297
	C3-4 elephant carcasses	154	±83	12	-	237	54%	12	1	0.008	1686
	elephant carcass one	12	±25	1	-	37	208%	1	0	0.001	138
	elephant carcass two	19	±27	2	-	46	142%	2	0	0.001	159
	elephant carcass three	87	±64	23	-	151	74%	7	1	0.005	993
	elephant carcass four	67	±60	7	-	127	90%	5	0	0.004	859

* As mentioned in Craig & Gibson (2019), Namibia has in the past removed carcasses from the field in this region as part of a monitoring program. While this practice has been discontinued it may result in an understimate of category 3 & 4 carcasses and the all-carcass ratio for this zone.

Table 3.3: Elephant carcass estimates and associated statistics for the KAZA TFCA survey area, country, and each superstratum continued.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Zambia	all elephant carcasses	137	±77	60	-	214	56%	13	4	0.002	1520
	C1-2 elephant carcasses	10	±19	1	-	29	190%	1	0	0.000	84
	C3-4 elephant carcasses	127	±71	56	-	198	56%	12	4	0.002	1270
	elephant carcass one	Not observed in the sample						0	0		
	elephant carcass two	10	±19	1	-	29	190%	1	0	0.000	84
	elephant carcass three	119	±69	50	-	188	58%	11	2	0.002	1210
	elephant carcass four	8	±16	1	-	24	200%	1	2	0.000	60
Kafue	all elephant carcasses	129	±76	53	-	205	59%	12	4	0.002	1461
	C1-2 elephant carcasses	10	±19	1	-	29	190%	1	0	0.000	84
	C3-4 elephant carcasses	119	±69	50	-	188	58%	11	4	0.002	1210
	elephant carcass one	Not observed in the sample						0	0		
	elephant carcass two	10	±19	1	-	29	190%	1	0	0.000	84
	elephant carcass three	119	±69	50	-	188	58%	11	2	0.002	1210
	elephant carcass four	Not observed in the sample						0	2		
Sioma	all elephant carcasses	8	±16	1	-	24	200%	1	0	0.001	60
	C1-2 elephant carcasses	Not observed in the sample						0	0		
	C3-4 elephant carcasses	8	±16	1	-	24	200%	1	0	0.001	60
	elephant carcass one	Not observed in the sample						0	0		
	elephant carcass two	Not observed in the sample						0	0		
	elephant carcass three	Not observed in the sample						0	0		
	elephant carcass four	8	±16	1	-	24	200%	1	0	0.001	60
Zimbabwe	all elephant carcasses	5166	±612	4554	-	5778	12%	552	193	0.127	93958
	C1-2 elephant carcasses	64	±54	10	-	118	84%	7	3	0.002	697
	C3-4 elephant carcasses	5102	±609	4493	-	5711	12%	545	190	0.125	92795
	elephant carcass one	24	±29	3	-	53	121%	3	1	0.001	202
	elephant carcass two	40	±47	4	-	87	118%	4	2	0.001	504
	elephant carcass three	2194	±402	1792	-	2596	18%	214	106	0.054	40347
	elephant carcass four	2908	±382	2526	-	3290	13%	331	84	0.072	36795
North-West Matabeleland	all elephant carcasses	4427	±593	3834	-	5020	13%	443	190	0.177	87581
	C1-2 elephant carcasses	64	±54	10	-	118	84%	7	3	0.003	697
	C3-4 elephant carcasses	4363	±589	3774	-	4952	13%	436	187	0.174	86418
	elephant carcass one	24	±29	3	-	53	121%	3	1	0.001	202
	elephant carcass two	40	±47	4	-	87	118%	4	2	0.002	504
	elephant carcass three	2087	±399	1688	-	2486	19%	194	106	0.083	39588
	elephant carcass four	2275	±357	1918	-	2632	16%	242	81	0.091	31791
Sebungwe	all elephant carcasses	740	±159	581	-	899	21%	109	3	0.047	6377
	C1-2 elephant carcasses	Not observed in the sample						0	0		
	C3-4 elephant carcasses	740	±159	581	-	899	21%	109	3	0.047	6377
	elephant carcass one	Not observed in the sample						0	0		
	elephant carcass two	Not observed in the sample						0	0		
	elephant carcass three	106	±59	47	-	165	56%	20	0	0.007	759
	elephant carcass four	633	±140	493	-	773	22%	89	3	0.041	5004

Table 3.4: Live elephants and elephant carcasses counted on three reconnaissance flights outside of the survey area.

Zone	Species	No Seen	Comment
KAZA	all elephants all elephant carcasses	872 45	Summed from the three reconnaissance flights
Botswana	all elephants all elephant carcasses	288 44	Counted along the Boteti River near Rakops
Zambia Sioma	all elephants all elephant carcasses	552 0	Counted north of Sioma. Using photos, 508 indiv. were counted in a single herd
Zimbabwe North-West Matabeleland	all elephants all elephant carcasses	32 1	Counted in the Fuller Forest area, north of the Victoria Falls International airport

Table 3.5: Summary of carcass ratios for the KAZA TFCA survey area, country, and each superstratum. CR14 represents the all-carcass ratio (i.e., categories 1 through 4), while CR12 represents the fresh and recent carcass ratio (i.e., category 1 and 2 only).

	All Carcass Ratio	Fresh and Recent Carcass Ratio
Zone	CR14	CR12
KAZA	10.47%	0.51%
Angola	16.27%	0.57%
Botswana	12.80%	0.72%
Namibia	3.57%	0.43%
Kavango Zambezi	4.60%	0.49%
Khaudum Nyae-Nyae	2.07%	0.36%
Zambia	3.44%	0.26%
Kafue	3.25%	0.26%
Sioma	100%*	0.00%
Zimbabwe	7.36%	0.10%
North-West Matabeleland	6.71%	0.10%
Sebungwe	17.46%	0.00%

* Refer to the discussion in section 4.1.2

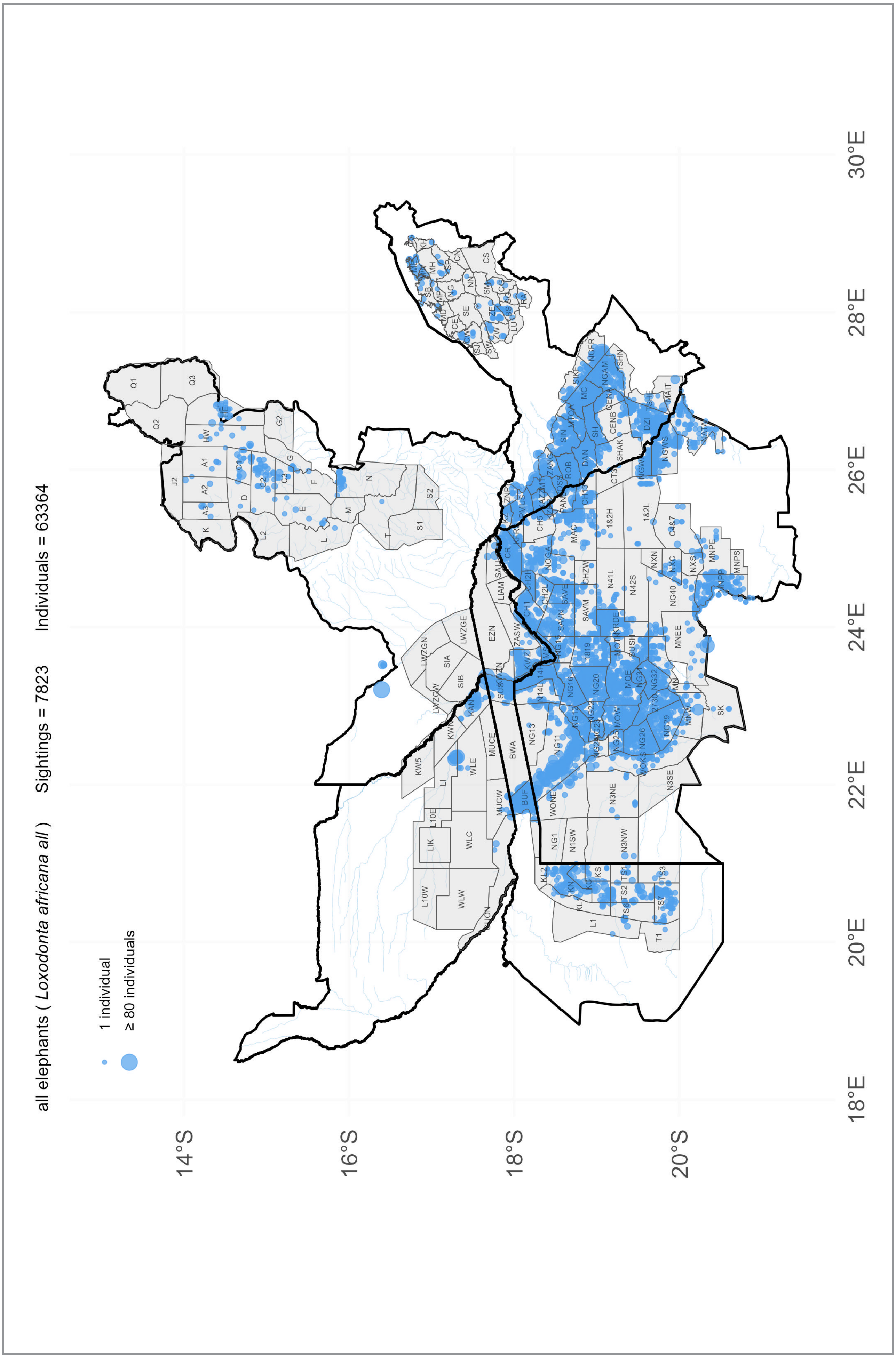


Figure 3.1: Spatial distribution all elephant observations in the KAZA TFCA survey area during the 2022 survey.

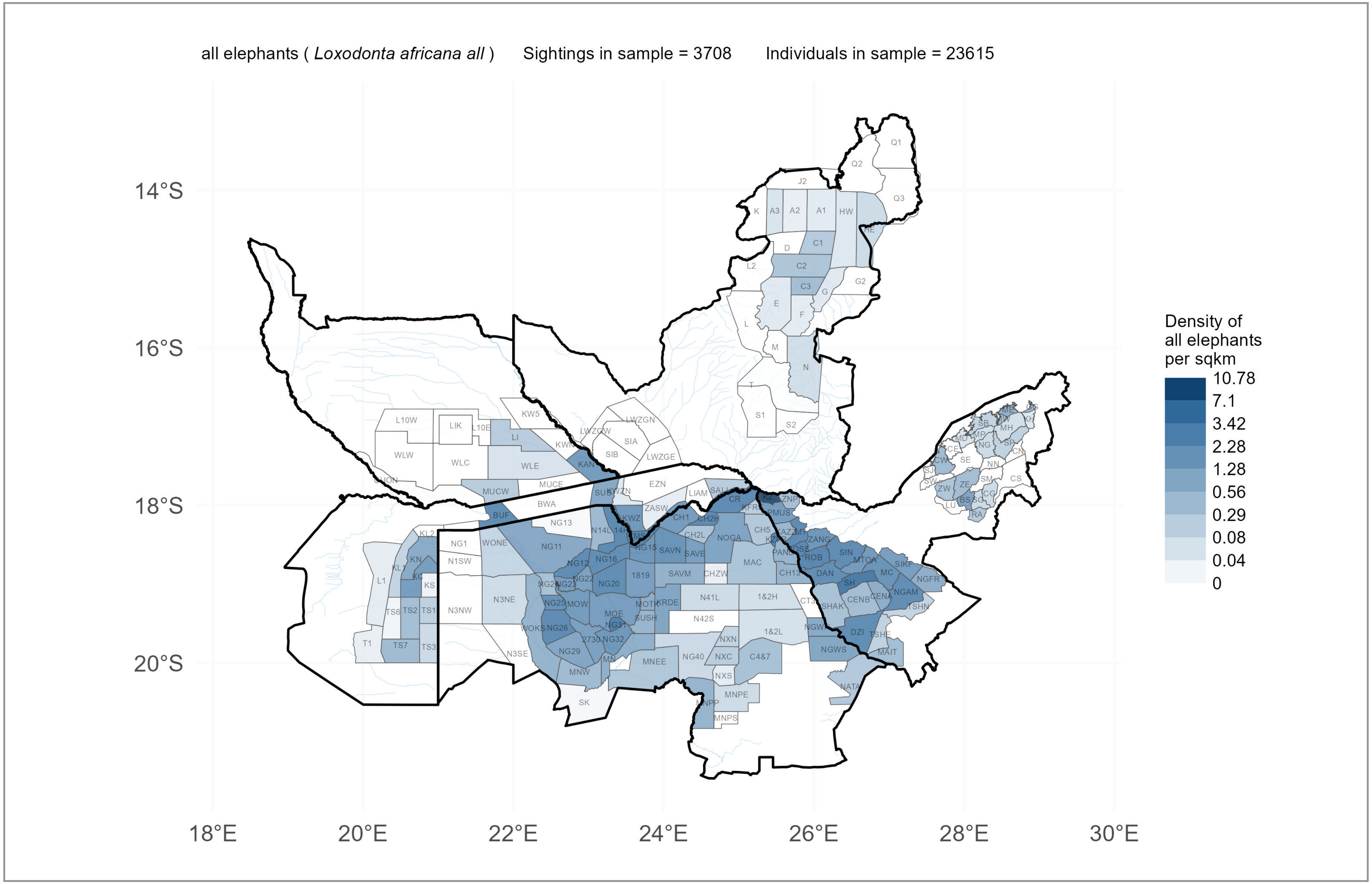


Figure 3.2: Estimated density of all elephants in the KAZA TFCA survey area during the 2022 survey.

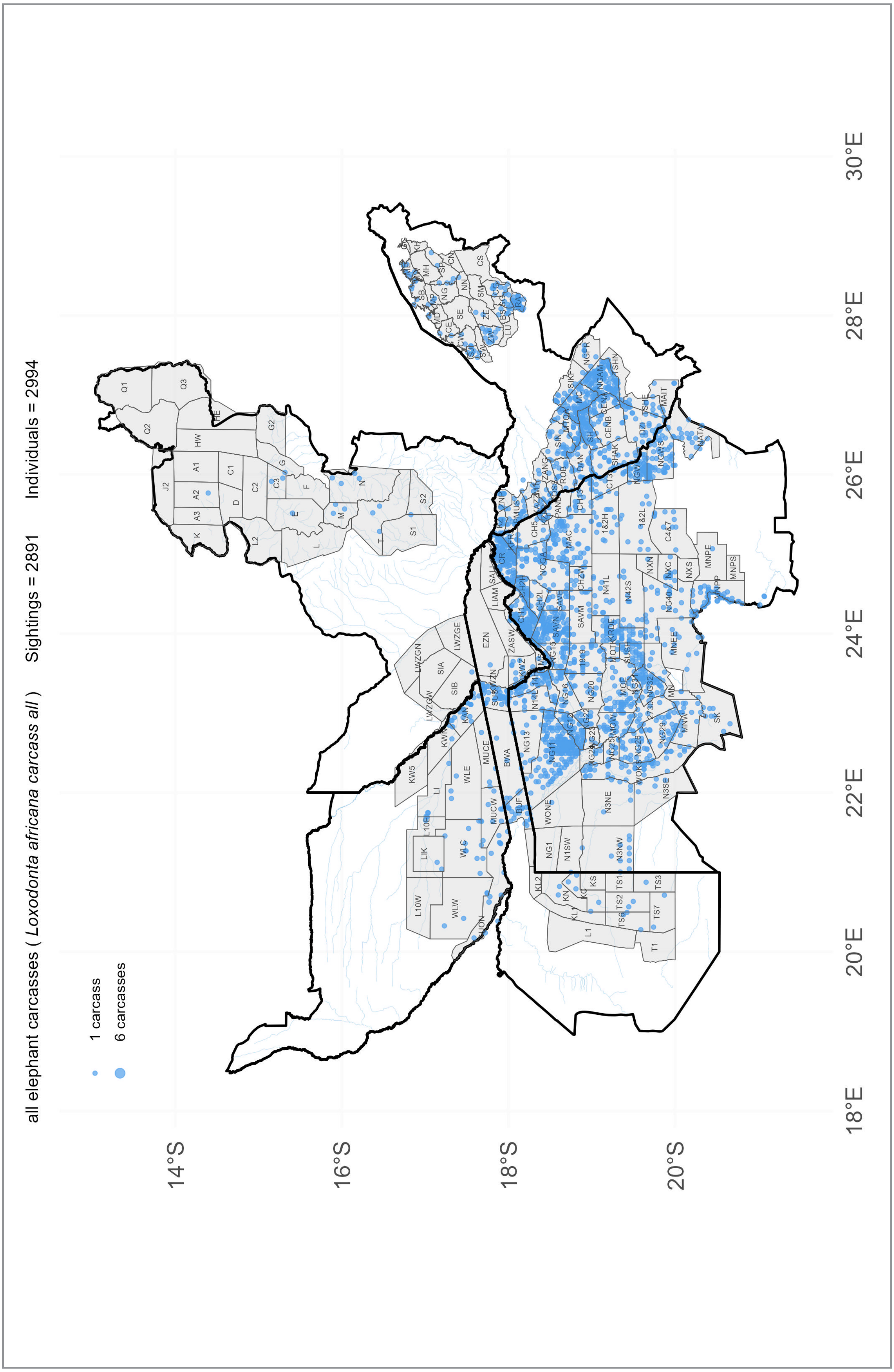


Figure 3.3: Spatial distribution of all elephant carcass observations (categories 1-4) in the KAZA TFCA survey area during the 2022 survey.

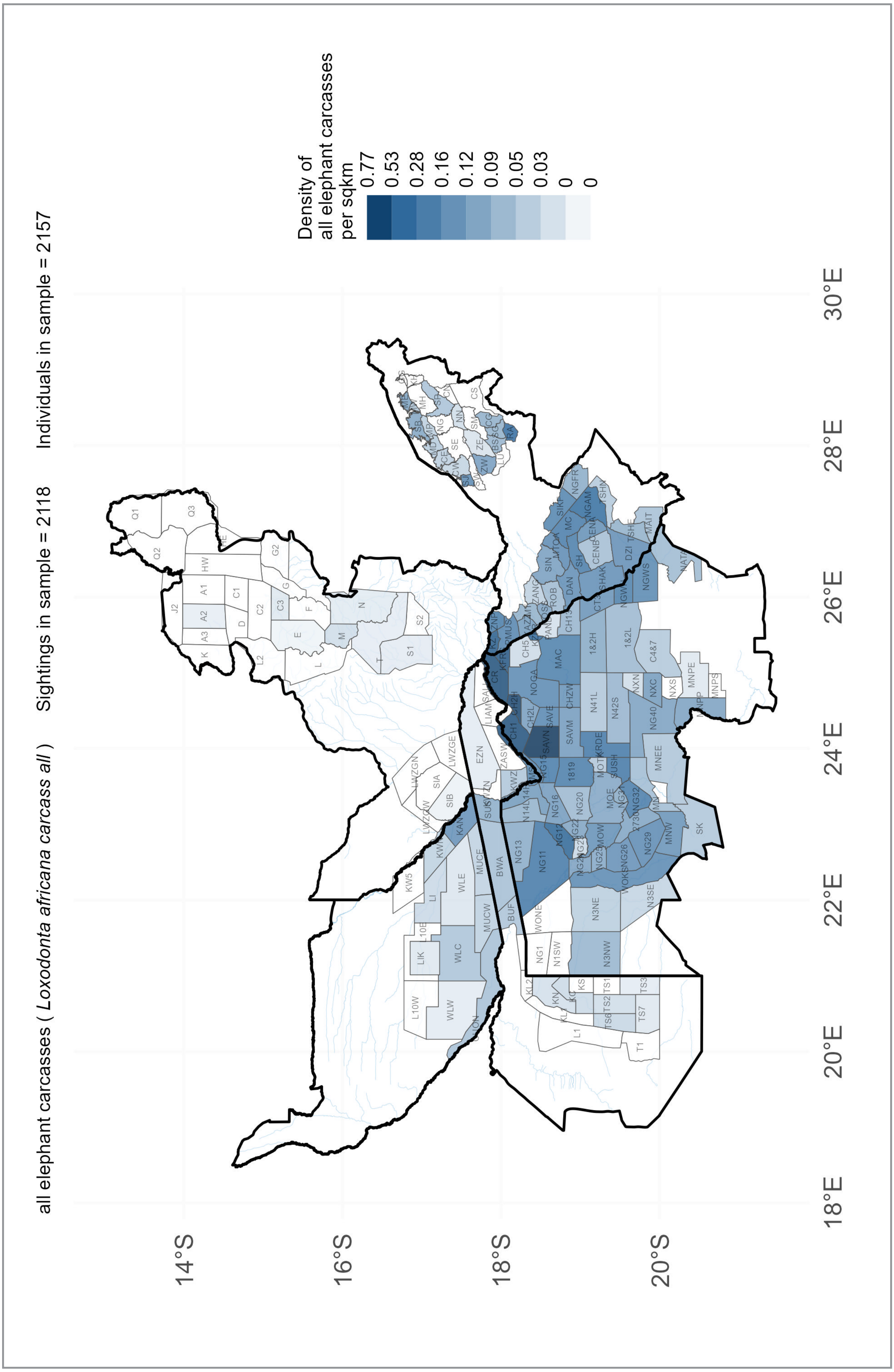


Figure 3.4: Estimated density of all elephant carcasses (categories 1-4) in the KAZA TFCA survey area during the 2022 survey.

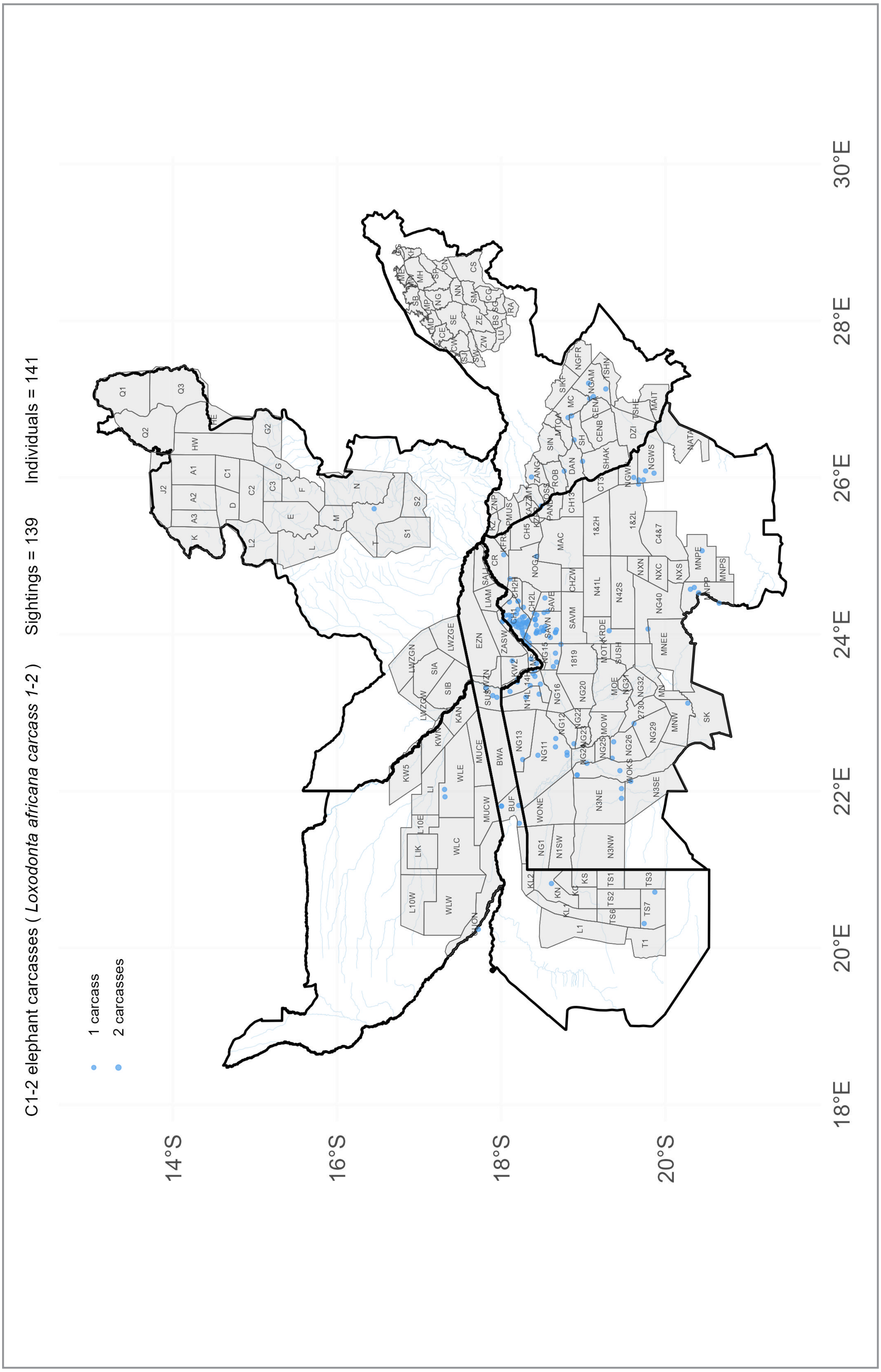


Figure 3.5: Spatial distribution of fresh and recent (categories 1-2) elephant carcass observations in the KAZA TFCA survey area during the 2022 survey.

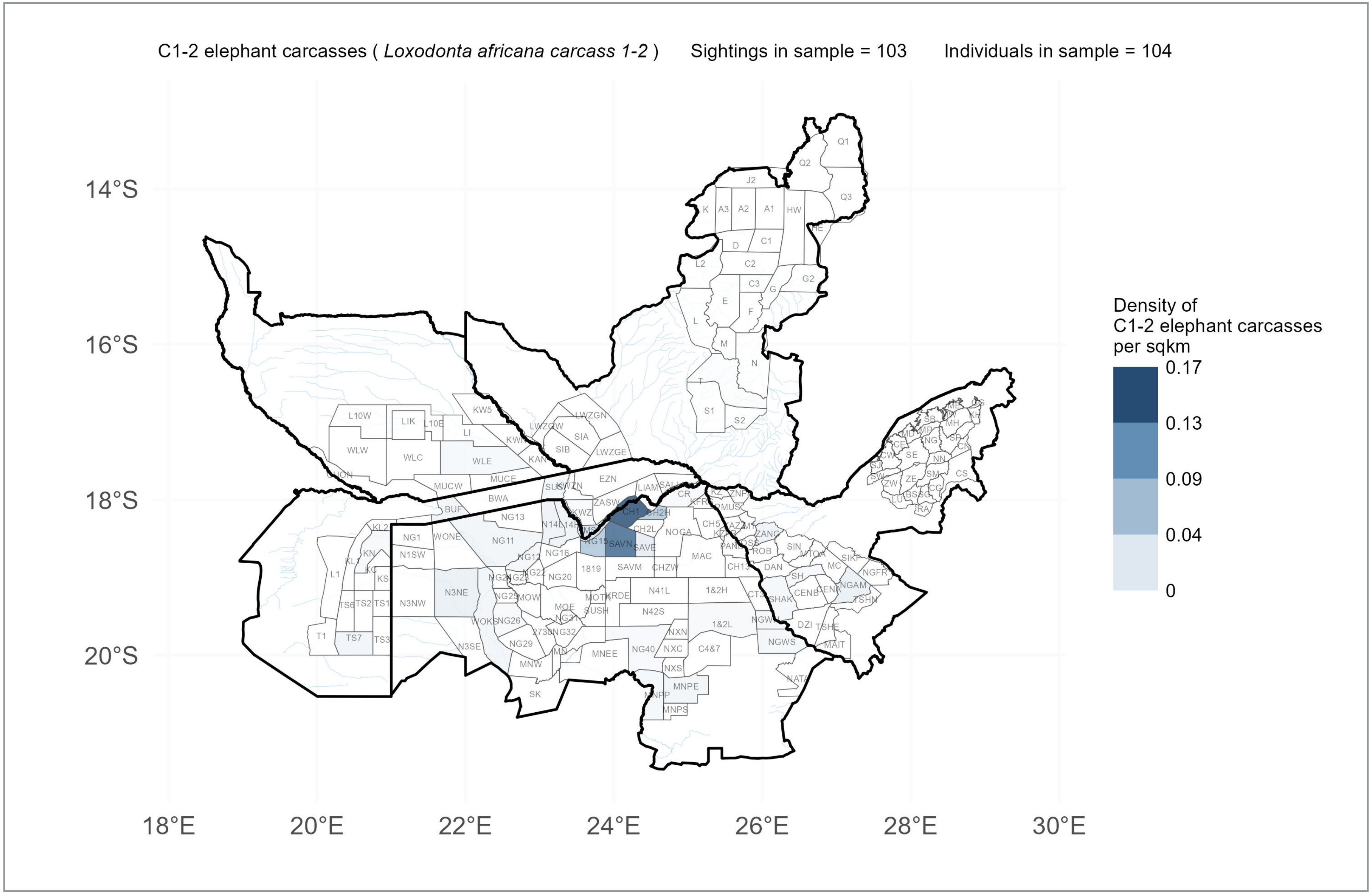


Figure 3.6: Estimated density of fresh and recent elephant carcasses (categories 1-2) in the KAZA TFCA survey area during the 2022 survey.

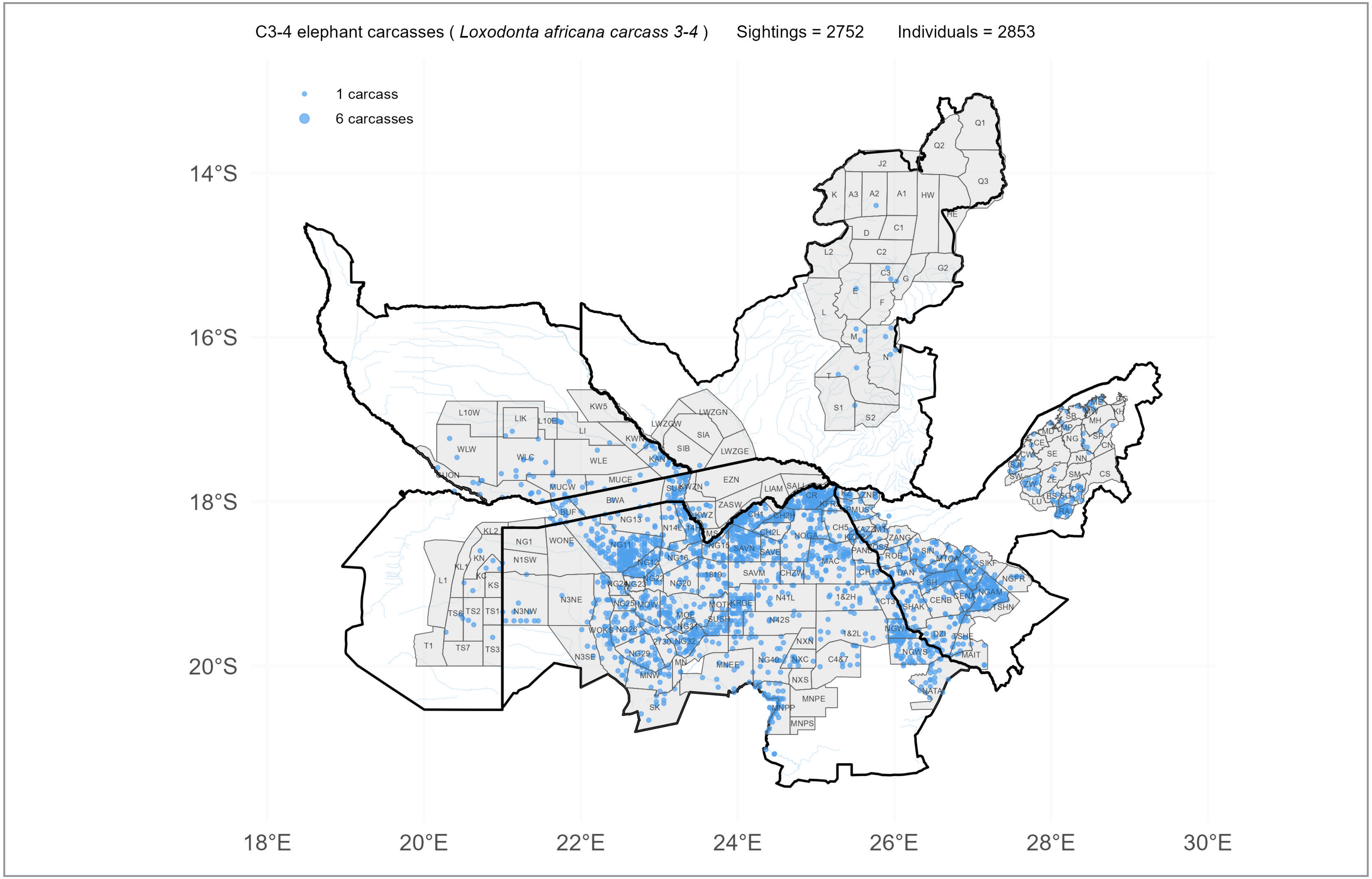


Figure 3.7: Spatial distribution of old and very old (categories 3-4) elephant carcass observations in the KAZA TFCA survey area during the 2022 survey.

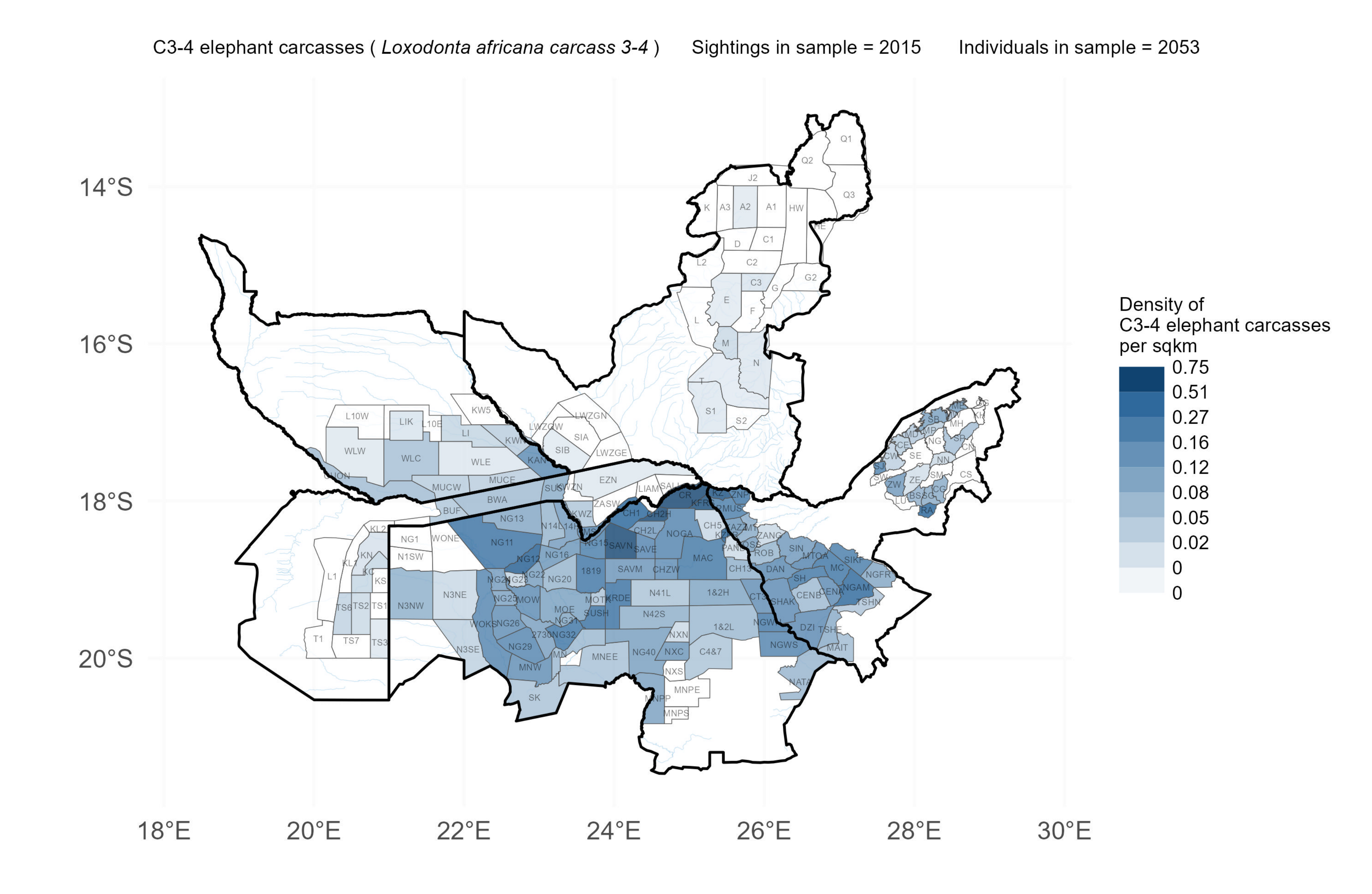


Figure 3.8: Estimated density of old and very old elephant carcasses (categories 3-4) in the KAZA TFCA survey area during the 2022 survey.

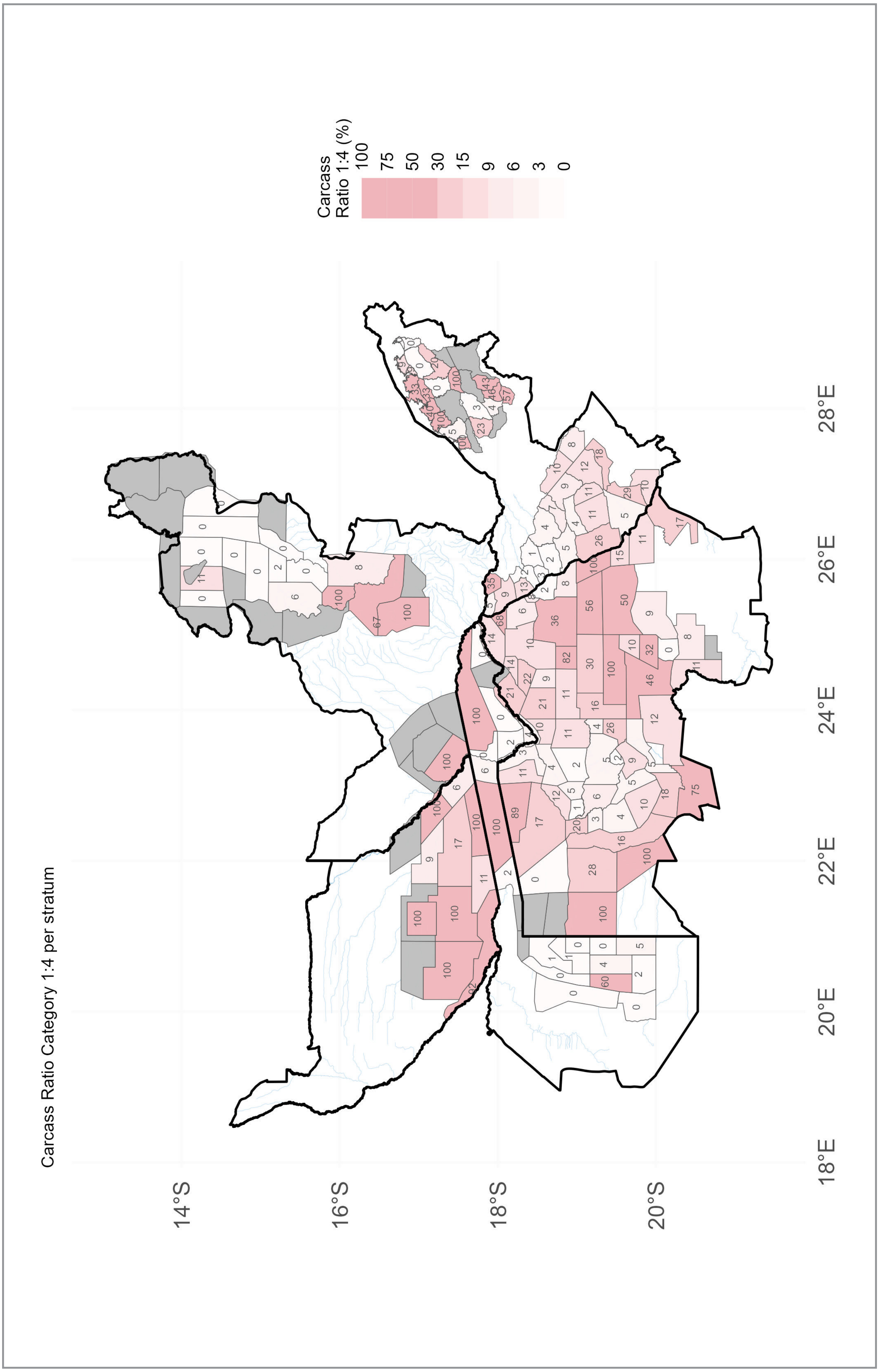


Figure 3.9: Choropleth map of the all-carcass ratio (categories 1-4) for each stratum within the KAZA TFCA survey area. The label shown in each stratum is the carcass ratio (%) obtained for that stratum.

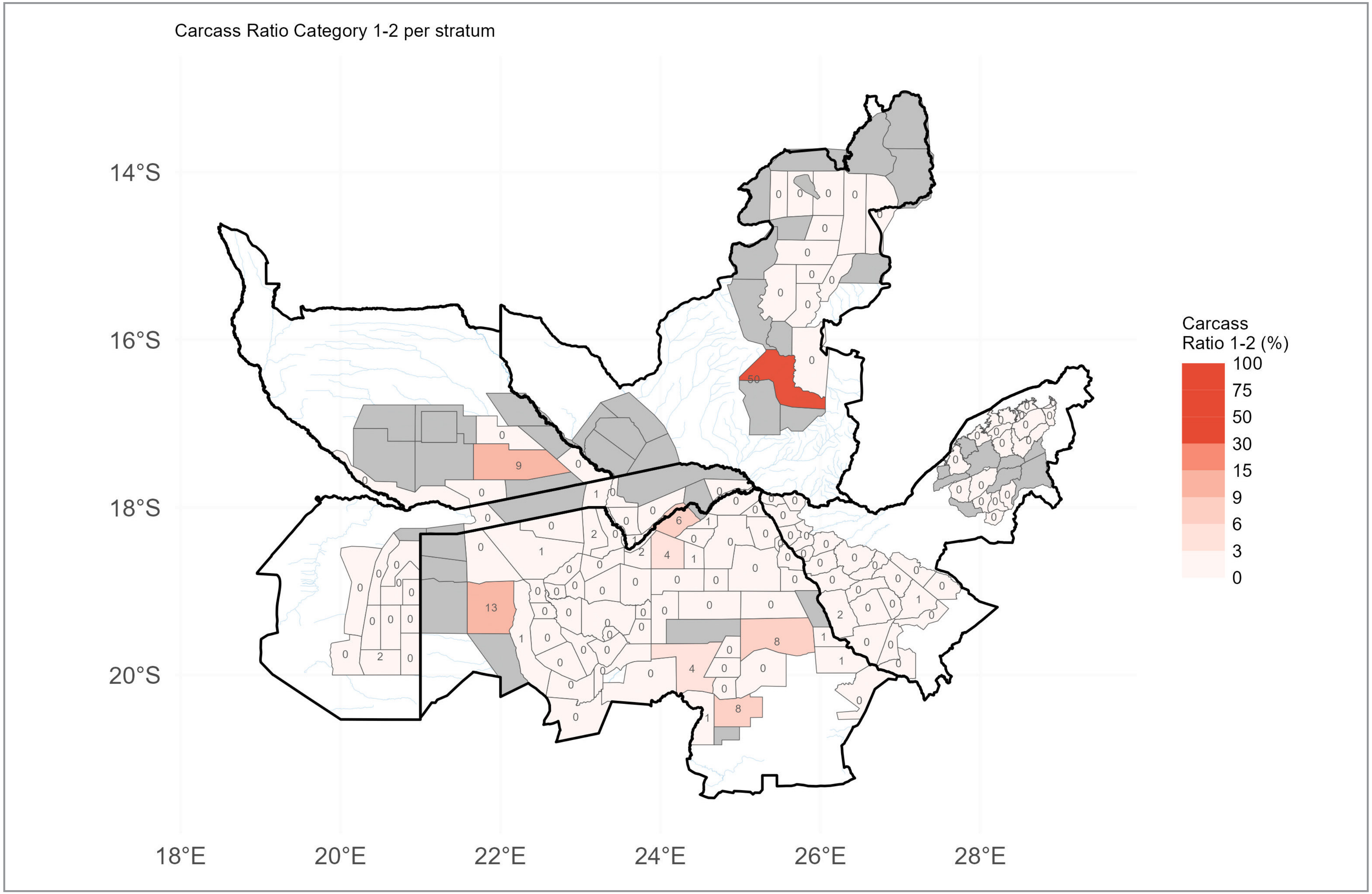


Figure 3.10: Choropleth map of the fresh and recent carcass ratio (categories 1 & 2) for each stratum within the KAZA TFCA survey area. The label shown in each stratum is the carcass ratio (%) obtained for that stratum.

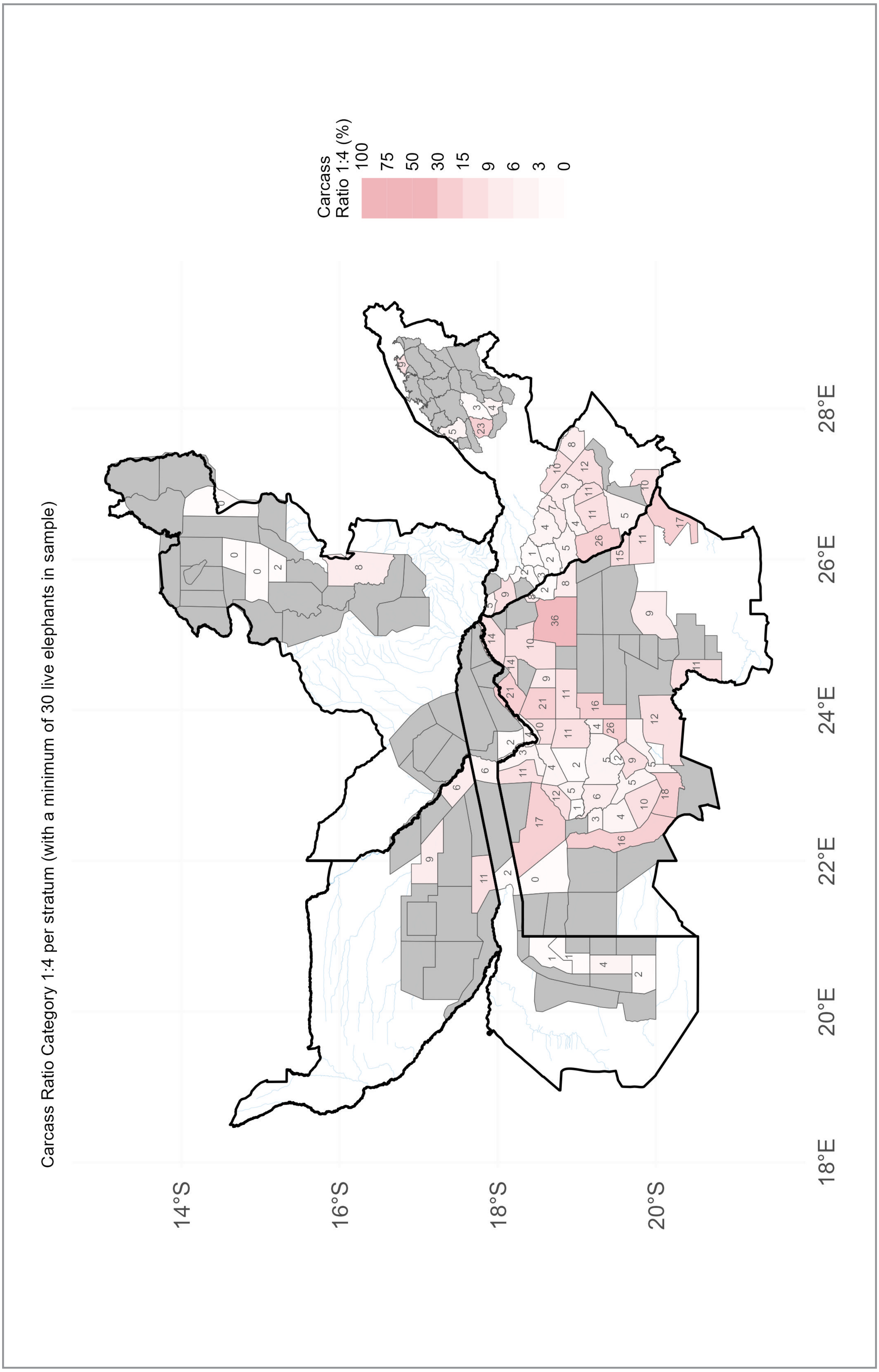


Figure 3.11: The all-carcass ratio (categories 1 to 4) filtered for strata where elephants were present (>30 live individuals in the sample) within the KAZA TFCA survey area. The label shown in each stratum is the carcass ratio (%) obtained for that stratum.

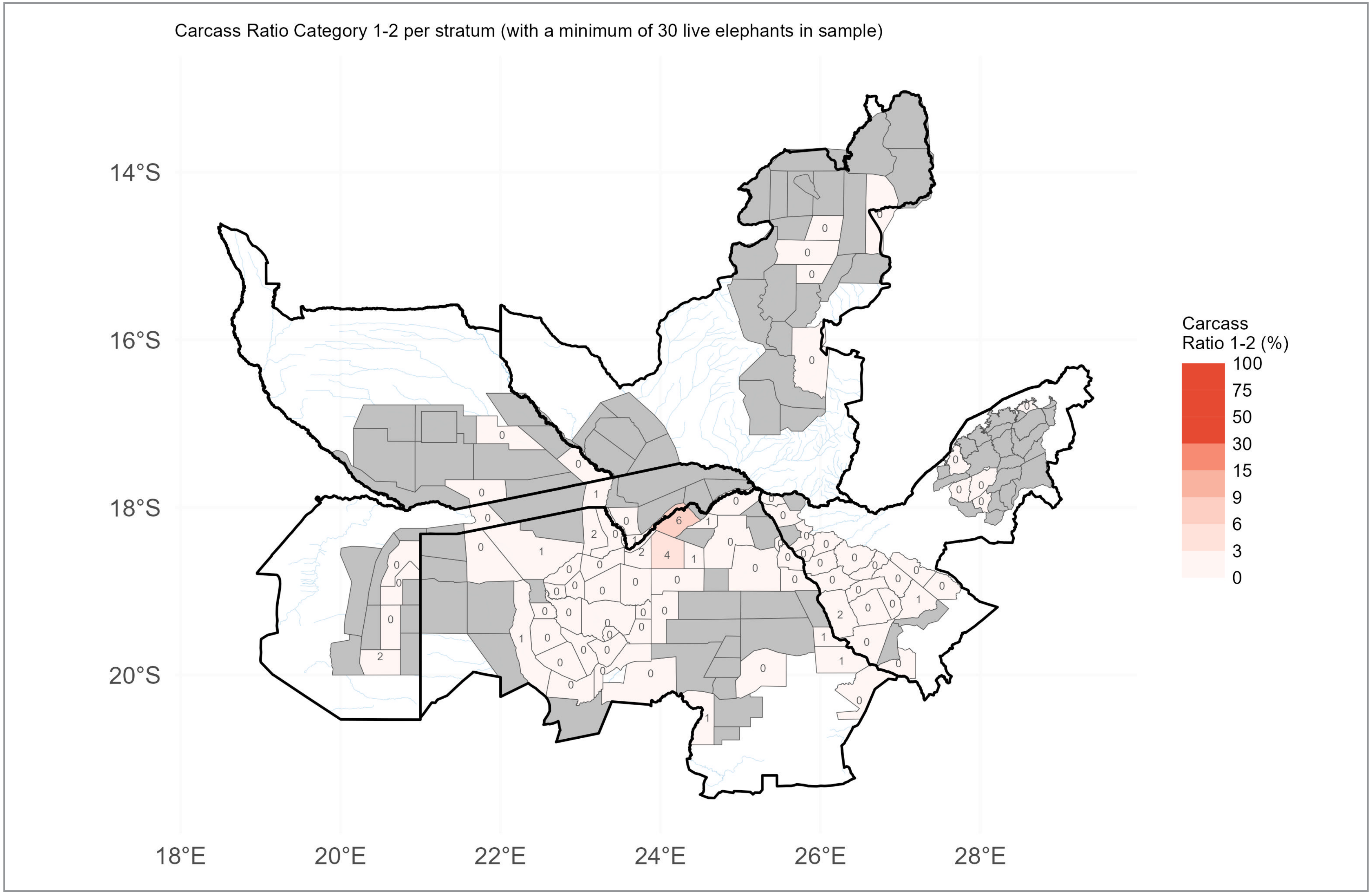


Figure 3.12: The fresh and recent carcass ratio (categories 1 & 2) filtered for strata where elephants were present (>30 live individuals in the sample) within the KAZA TFCA survey area. The label shown in each stratum is the carcass ratio (%) obtained for that stratum.

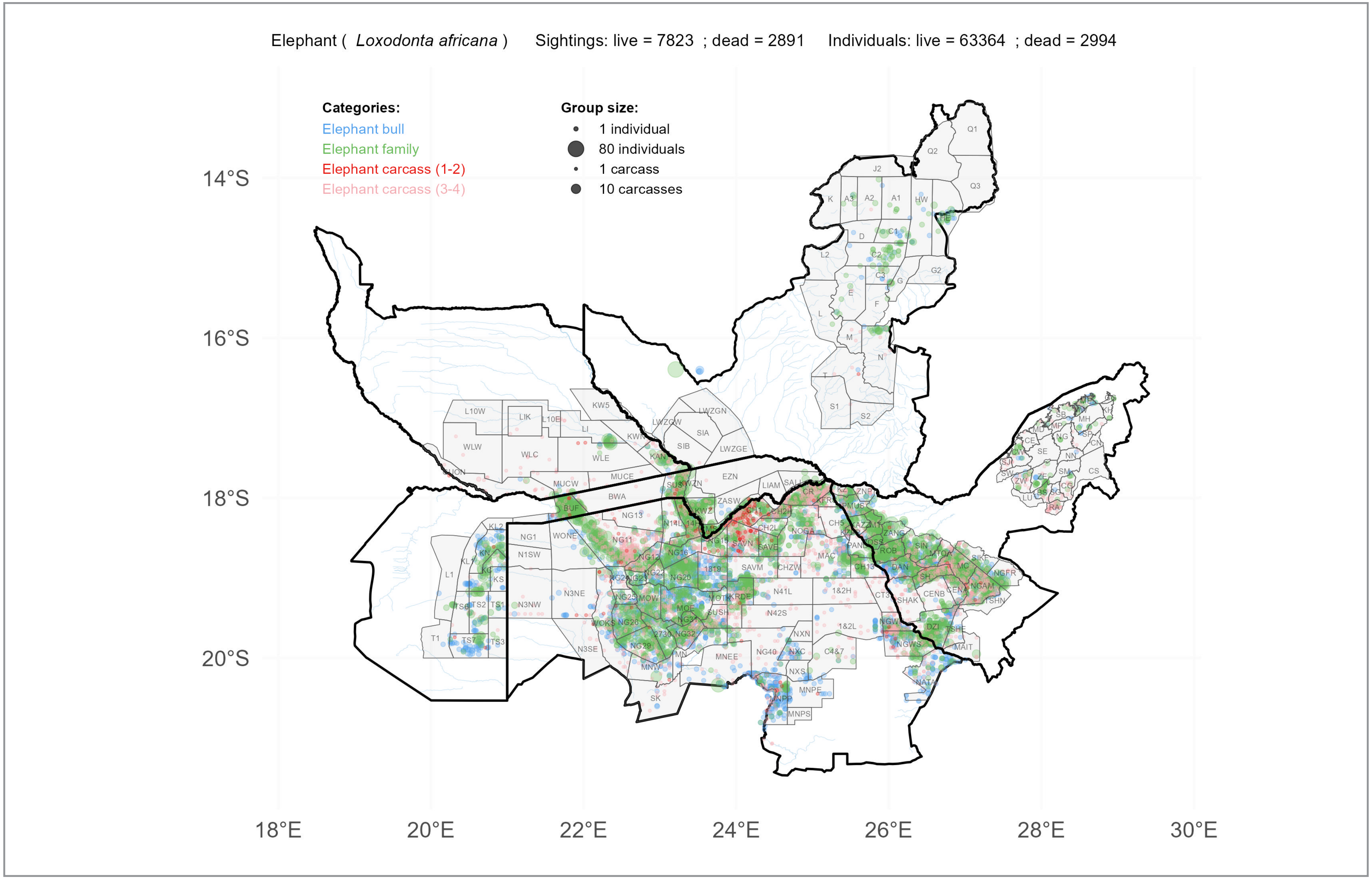


Figure 3.13: A composite map showing the spatial distribution of observations of elephant bulls, elephant cows, carcass categories 1-2, and 3-4 in the KAZA TFCA survey area during the 2022 survey.

3.1.2 Estimates and distribution for all large herbivores (wild and domestic) in each zone

Population estimates are provided for all species at the country and superstratum levels. Sheep and goats are often found in mixed herds and are counted together as a single species (shoat). Maps of distribution and density for select species (with at least 100 observations within the search strip and a PRP of less than 40%) are provided in figures 3.14 to 3.57. Maps for the excluded species with very few sightings are included in the database at all scales but are not useful for KAZA-scale maps presented here.

Table 3.6: Population estimates and associated statistics for all species in the KAZA TFCA survey area.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
KAZA	all elephants	227900	±16743	211157	-	244643	7%	23615	38877	0.733	72191578
KAZA	elephant bulls	32559	±2789	29770	-	35348	9%	3005	5384	0.105	2012566
KAZA	elephant family	195342	±16180	179162	-	211522	8%	20610	33493	0.628	67353691
KAZA	all elephant carcasses	26641	±1645	24996	-	28286	6%	2157	792	0.086	698728
KAZA	C1-2 elephant carcasses	1165	±290	875	-	1455	25%	104	34	0.004	20993
KAZA	C3-4 elephant carcasses	25476	±1595	23881	-	27071	6%	2053	758	0.082	656417
KAZA	elephant carcass one	277	±115	162	-	392	42%	29	14	0.001	3274
KAZA	elephant carcass two	888	±266	622	-	1154	30%	75	20	0.003	17388
KAZA	elephant carcass three	9753	±998	8755	-	10751	10%	780	307	0.031	256754
KAZA	elephant carcass four	15722	±1148	14574	-	16870	7%	1273	451	0.051	337767
Wildlife											
KAZA	baboon	7053	±4253	2800	-	11306	60%	552	17	0.023	4150732
KAZA	buffalo	78264	±19558	58706	-	97822	25%	8898	13399	0.252	97827758
KAZA	bushbuck	746	±255	491	-	1001	34%	72	0	0.002	16742
KAZA	bushpig	1419	±640	779	-	2059	45%	100	37	0.005	102506
KAZA	duiker	16254	±1569	14685	-	17823	10%	952	83	0.052	623031
KAZA	eland	6306	±3422	2884	-	9728	54%	453	474	0.020	2843404
KAZA	giraffe	12771	±1789	10982	-	14560	14%	1139	526	0.041	823768
KAZA	grysbok	277	±211	66	-	488	76%	14	0	0.001	10169
KAZA	hartebeest	10905	±2538	8367	-	13443	23%	1052	845	0.035	1659192
KAZA	hippopotamus	17006	±2940	14066	-	19946	17%	1966	283	0.055	2227703
KAZA	impala	100028	±12695	87333	-	112723	13%	11171	2532	0.322	41376435
KAZA	klipspringer	40	±60	4	-	100	150%	4	0	0.000	816
KAZA	kudu	16714	±2537	14177	-	19251	15%	1329	339	0.054	1647757
KAZA	oribi	69	±78	7	-	147	113%	7	4	0.000	1553
KAZA	oryx	4373	±1343	3030	-	5716	31%	267	120	0.014	414461
KAZA	ostrich	7580	±1807	5773	-	9387	24%	426	218	0.024	818290
KAZA	puku	13809	±4943	8866	-	18752	36%	1410	1456	0.044	6171251
KAZA	red lechwe	137959	±17389	120570	-	155348	13%	19392	4386	0.444	74852756
KAZA	reedbuck	3386	±669	2717	-	4055	20%	348	20	0.011	115009
KAZA	roan	7428	±1917	5511	-	9345	26%	676	629	0.024	938999
KAZA	sable	39966	±7386	32580	-	47352	18%	3447	3309	0.129	13851249
KAZA	sitatunga	330	±157	173	-	487	48%	27	1	0.001	6076
KAZA	springbok	225	±657	12	-	882	292%	12	0	0.001	43309
KAZA	tsessebe	5811	±1607	4204	-	7418	28%	566	241	0.019	644185
KAZA	warthog	23420	±2309	21111	-	25729	10%	2525	444	0.075	1378554
KAZA	waterbuck	6264	±1529	4735	-	7793	24%	688	184	0.020	599344
KAZA	wildebeest	22245	±8496	13749	-	30741	38%	1809	2227	0.072	14723617
KAZA	zebra	88250	±28059	60191	-	116309	32%	7337	3651	0.284	184678465
Livestock											
KAZA	cattle	536623	±54295	482328	-	590918	10%	27854	6964	1.726	743907182
KAZA	donkey	20843	±4252	16591	-	25095	20%	1121	108	0.067	4597537
KAZA	horse	5214	±2422	2792	-	7636	46%	213	72	0.017	1365162
KAZA	shoat	173746	±22940	150806	-	196686	13%	8541	930	0.559	131278192

Table 3.7: Population estimates and associated statistics for all species in the Angola portion of the KAZA TFCA survey area.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Angola	all elephants	5983	±6461	355	-	12444	108%	355	633	0.165	9384212
Angola	elephant bulls	303	±337	17	-	640	111%	17	29	0.008	27266
Angola	elephant family	5679	±6466	338	-	12145	114%	338	604	0.156	9360772
Angola	all elephant carcasses	1163	±338	825	-	1501	29%	58	19	0.032	28880
Angola	C1-2 elephant carcasses	34	±76	1	-	110	224%	1	2	0.001	1183
Angola	C3-4 elephant carcasses	1129	±333	796	-	1462	29%	57	17	0.031	27975
Angola	elephant carcass one	Not observed in the sample						0	0		
Angola	elephant carcass two	34	±76	1	-	110	224%	1	2	0.001	1183
Angola	elephant carcass three	589	±272	317	-	861	46%	30	7	0.016	18340
Angola	elephant carcass four	540	±226	314	-	766	42%	27	10	0.015	12857
Wildlife											
Angola	baboon	2822	±4097	95	-	6919	145%	95	0	0.078	3735717
Angola	buffalo	13134	±10459	2675	-	23593	80%	697	792	0.361	26114687
Angola	bushbuck	57	±84	3	-	141	147%	3	0	0.002	1739
Angola	bushpig	535	±496	39	-	1031	93%	19	1	0.015	57693
Angola	duiker	7107	±1189	5918	-	8296	17%	293	24	0.196	337932
Angola	eland	348	±474	16	-	822	136%	16	102	0.010	50401
Angola	giraffe	393	±397	20	-	790	101%	20	1	0.011	37299
Angola	grysbok	206	±192	14	-	398	93%	6	0	0.006	7642
Angola	hartebeest	Not observed in the sample						0	0		
Angola	hippopotamus	94	±182	6	-	276	194%	6	0	0.003	7175
Angola	impala	Not observed in the sample						0	0		
Angola	klipspringer	Not observed in the sample						0	0		
Angola	kudu	4574	±1827	2747	-	6401	40%	203	44	0.126	827317
Angola	oribi	Not observed in the sample						0	0		
Angola	oryx	Not observed in the sample						0	0		
Angola	ostrich	180	±139	41	-	319	77%	9	10	0.005	4840
Angola	puku	63	±147	4	-	210	233%	4	0	0.002	4680
Angola	red lechwe	866	±2045	55	-	2911	236%	55	0	0.024	909124
Angola	reedbuck	654	±360	294	-	1014	55%	38	7	0.018	30766
Angola	roan	2025	±1117	908	-	3142	55%	99	133	0.056	294844
Angola	sable	11787	±5235	6552	-	17022	44%	511	287	0.324	6651631
Angola	sitatunga	144	±140	8	-	284	97%	8	1	0.004	4723
Angola	springbok	Not observed in the sample						0	0		
Angola	tsessebe	285	±333	17	-	618	117%	17	26	0.008	26306
Angola	warthog	721	±444	277	-	1165	62%	32	5	0.020	48975
Angola	waterbuck	142	±330	9	-	472	232%	9	0	0.004	23694
Angola	wildebeest	755	±1154	38	-	1909	153%	38	52	0.021	306980
Angola	zebra	425	±717	27	-	1142	169%	27	0	0.012	111695
Livestock											
Angola	cattle	18043	±5747	12296	-	23790	32%	999	583	0.496	8336501
Angola	donkey	195	±295	10	-	490	151%	10	6	0.005	21082
Angola	horse	Not observed in the sample						0	0		
Angola	shoat	1451	±1376	75	-	2827	95%	68	18	0.040	459339

Table 3.8: Population estimates and associated statistics for all species in the Botswana portion of the KAZA TFCA survey area.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Botswana	all elephants	131909	±11933	119976	-	143842	9%	11944	20875	1.067	36767969
Botswana	elephant bulls	21167	±2363	18804	-	23530	11%	1741	3280	0.171	1439801
Botswana	elephant family	110742	±11364	99378	-	122106	10%	10203	17595	0.895	33317299
Botswana	all elephant carcasses	19371	±1471	17900	-	20842	8%	1430	564	0.157	556989
Botswana	C1-2 elephant carcasses	962	±270	692	-	1232	28%	79	29	0.008	17924
Botswana	C3-4 elephant carcasses	18409	±1422	16987	-	19831	8%	1351	535	0.149	519720
Botswana	elephant carcass one	228	±105	123	-	333	46%	22	13	0.002	2696
Botswana	elephant carcass two	734	±250	484	-	984	34%	57	16	0.006	15075
Botswana	elephant carcass three	6417	±847	5570	-	7264	13%	489	188	0.052	183747
Botswana	elephant carcass four	11992	±1061	10931	-	13053	9%	862	347	0.097	286656
Wildlife											
Botswana	baboon	3180	±1131	2049	-	4311	36%	326	9	0.026	320475
Botswana	buffalo	37006	±13557	23449	-	50563	37%	3824	5367	0.299	46504081
Botswana	bushbuck	162	±136	26	-	298	84%	10	0	0.001	4264
Botswana	bushpig	159	±160	15	-	319	101%	15	1	0.001	6364
Botswana	duiker	1586	±494	1092	-	2080	31%	69	4	0.013	60266
Botswana	eland	3111	±2888	223	-	5999	93%	215	95	0.025	1866210
Botswana	giraffe	9512	±1527	7985	-	11039	16%	821	347	0.077	595790
Botswana	grysbok	51	±100	6	-	151	196%	6	0	0.000	2350
Botswana	hartebeest	Not observed in the sample						0	0		
Botswana	hippopotamus	8649	±1660	6989	-	10309	19%	899	64	0.070	697225
Botswana	impala	58007	±8213	49794	-	66220	14%	5636	351	0.469	17209885
Botswana	klipspringer	Not observed in the sample						0	0		
Botswana	kudu	5147	±1315	3832	-	6462	26%	339	77	0.042	427713
Botswana	oribi	Not observed in the sample						0	0		
Botswana	oryx	2695	±1257	1438	-	3952	47%	131	54	0.022	342148
Botswana	ostrich	6124	±1728	4396	-	7852	28%	322	135	0.050	742780
Botswana	puku	101	±136	24	-	237	135%	24	0	0.001	4645
Botswana	red lechwe	105155	±16468	88687	-	121623	16%	11335	580	0.850	66245458
Botswana	reedbuck	1397	±387	1010	-	1784	28%	142	0	0.011	37809
Botswana	roan	564	±322	242	-	886	57%	62	14	0.005	26090
Botswana	sable	3901	±1337	2564	-	5238	34%	423	258	0.032	438749
Botswana	sitatunga	156	±64	92	-	220	41%	16	0	0.001	950
Botswana	springbok	206	±660	10	-	866	320%	10	0	0.002	42970
Botswana	tsessebe	5338	±1572	3766	-	6910	29%	497	197	0.043	613525
Botswana	warthog	6893	±1108	5785	-	8001	16%	636	24	0.056	311302
Botswana	waterbuck	1882	±916	966	-	2798	49%	197	3	0.015	205469
Botswana	wildebeest	15610	±8288	7322	-	23898	53%	1154	798	0.126	13059837
Botswana	zebra	64728	±27232	37496	-	91960	42%	5164	2293	0.523	170937482
Livestock											
Botswana	cattle	155721	±28714	127007	-	184435	18%	8217	1937	1.259	206163642
Botswana	donkey	14783	±3692	11091	-	18475	25%	815	86	0.120	3449786
Botswana	horse	5116	±2430	2686	-	7546	47%	208	64	0.041	1371169
Botswana	shoat	54322	±18065	36257	-	72387	33%	2299	279	0.439	75430151

Table 3.9: Population estimates and associated statistics for all species in the Namibia portion of the KAZA TFCA survey area.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Namibia	all elephants	21090	±3888	17202	-	24978	18%	3770	5325	0.580	3853056
Namibia	elephant bulls	3106	±796	2310	-	3902	26%	407	557	0.085	160151
Namibia	elephant family	17984	±3764	14220	-	21748	21%	3363	4768	0.495	3607901
Namibia	all elephant carcasses	780	±251	529	-	1031	32%	104	12	0.021	14829
Namibia	C1-2 elephant carcasses	92	±57	35	-	149	62%	16	0	0.003	798
Namibia	C3-4 elephant carcasses	688	±246	442	-	934	36%	88	12	0.019	14014
Namibia	elephant carcass one	23	±27	4	-	50	117%	4	0	0.001	172
Namibia	elephant carcass two	69	±51	18	-	120	74%	12	0	0.002	631
Namibia	elephant carcass three	422	±230	192	-	652	55%	36	4	0.012	11688
Namibia	elephant carcass four	266	±100	166	-	366	38%	52	8	0.007	2534
Wildlife											
Namibia	baboon	192	±135	57	-	327	70%	47	0	0.005	4554
Namibia	buffalo	10911	±3571	7340	-	14482	33%	2603	2376	0.300	3228809
Namibia	bushbuck	92	±122	12	-	214	133%	12	0	0.003	3611
Namibia	bushpig	101	±191	5	-	292	189%	5	24	0.003	7567
Namibia	duiker	1829	±551	1278	-	2380	30%	78	2	0.050	74749
Namibia	eland	1583	±1634	90	-	3217	103%	90	54	0.044	629052
Namibia	giraffe	817	±567	250	-	1384	69%	107	15	0.022	75663
Namibia	grysbok	10	±19	1	-	29	190%	1	0	0.000	84
Namibia	hartebeest	Not observed in the sample						0	2		
Namibia	hippopotamus	2447	±1363	1084	-	3810	56%	506	44	0.067	451714
Namibia	impala	3635	±1003	2632	-	4638	28%	894	79	0.100	256509
Namibia	klipspringer	Not observed in the sample						0	0		
Namibia	kudu	1529	±448	1081	-	1977	29%	217	39	0.042	49924
Namibia	oribi	Not observed in the sample						0	0		
Namibia	oryx	1582	±527	1055	-	2109	33%	129	66	0.044	70359
Namibia	ostrich	971	±418	553	-	1389	43%	83	69	0.027	43620
Namibia	puku	13	±15	4	-	28	115%	4	1	0.000	58
Namibia	red lechwe	9109	±2183	6926	-	11292	24%	2257	228	0.251	1168308
Namibia	reedbuck	287	±147	140	-	434	51%	66	1	0.008	5378
Namibia	roan	1256	±601	655	-	1857	48%	173	19	0.035	90515
Namibia	sable	3430	±1479	1951	-	4909	43%	732	182	0.094	530619
Namibia	sitatunga	Not observed in the sample						0	0		
Namibia	springbok	19	±39	2	-	58	205%	2	0	0.001	338
Namibia	tsessebe	168	±132	36	-	300	79%	51	16	0.005	4291
Namibia	warthog	3187	±895	2292	-	4082	28%	583	39	0.088	197988
Namibia	waterbuck	141	±123	18	-	264	87%	38	6	0.004	3740
Namibia	wildebeest	3076	±1744	1332	-	4820	57%	327	367	0.085	748802
Namibia	zebra	12741	±5826	6915	-	18567	46%	1366	898	0.350	8308497
Livestock											
Namibia	cattle	157500	±41694	115806	-	199194	26%	8007	990	4.331	414058239
Namibia	donkey	617	±716	22	-	1333	116%	22	4	0.017	86878
Namibia	horse	104	±142	8	-	246	137%	5	8	0.003	4499
Namibia	shoat	13639	±7852	5787	-	21491	58%	614	43	0.375	14153770

Table 3.10: Population estimates and associated statistics for all species in the Kavango Zambezi superstratum (Namibia).

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Kavango Zambezi	all elephants	12345	±2519	9826	-	14864	20%	3008	4220	0.684	1611432
Kavango Zambezi	elephant bulls	1069	±301	768	-	1370	28%	251	276	0.059	22941
Kavango Zambezi	elephant family	11276	±2476	8800	-	13752	22%	2757	3944	0.624	1557452
Kavango Zambezi	all elephant carcasses	595	±238	357	-	833	40%	89	11	0.033	12880
Kavango Zambezi	C1-2 elephant carcasses	61	±46	15	-	107	75%	13	0	0.003	501
Kavango Zambezi	C3-4 elephant carcasses	534	±235	299	-	769	44%	76	11	0.030	12328
Kavango Zambezi	elephant carcass one	11	±12	3	-	23	109%	3	0	0.001	34
Kavango Zambezi	elephant carcass two	50	±45	10	-	95	90%	10	0	0.003	472
Kavango Zambezi	elephant carcass three	336	±224	112	-	560	67%	29	3	0.019	10696
Kavango Zambezi	elephant carcass four	199	±83	116	-	282	42%	47	8	0.011	1675
Wildlife											
Kavango Zambezi	baboon	192	±135	57	-	327	70%	47	0	0.011	4554
Kavango Zambezi	buffalo	10830	±3569	7261	-	14399	33%	2597	2334	0.600	3224026
Kavango Zambezi	bushbuck	92	±122	12	-	214	133%	12	0	0.005	3611
Kavango Zambezi	bushpig	6	±11	2	-	17	183%	2	24	0.000	30
Kavango Zambezi	duiker	694	±340	354	-	1034	49%	26	1	0.038	27903
Kavango Zambezi	eland	38	±51	12	-	89	134%	12	15	0.002	616
Kavango Zambezi	giraffe	214	±91	123	-	305	43%	62	3	0.012	2065
Kavango Zambezi	grysbok	Not observed in the sample						0	0		
Kavango Zambezi	hartebeest	Not observed in the sample						0	0		
Kavango Zambezi	hippopotamus	2447	±1363	1084	-	3810	56%	506	44	0.136	451714
Kavango Zambezi	impala	3635	±1003	2632	-	4638	28%	894	79	0.201	256509
Kavango Zambezi	klipspringer	Not observed in the sample						0	0		
Kavango Zambezi	kudu	690	±232	458	-	922	34%	156	13	0.038	13030
Kavango Zambezi	oribi	Not observed in the sample						0	0		
Kavango Zambezi	oryx	Not observed in the sample						0	0		
Kavango Zambezi	ostrich	212	±190	29	-	402	90%	29	14	0.012	8665
Kavango Zambezi	puku	13	±15	4	-	28	115%	4	1	0.001	58
Kavango Zambezi	red lechwe	9109	±2183	6926	-	11292	24%	2257	228	0.504	1168308
Kavango Zambezi	reedbuck	287	±147	140	-	434	51%	66	1	0.016	5378
Kavango Zambezi	roan	319	±141	178	-	460	44%	81	18	0.018	4915
Kavango Zambezi	sable	3430	±1479	1951	-	4909	43%	732	182	0.190	530619
Kavango Zambezi	sitatunga	Not observed in the sample						0	0		
Kavango Zambezi	springbok	Not observed in the sample						0	0		
Kavango Zambezi	tsessebe	168	±132	51	-	300	79%	51	1	0.009	4291
Kavango Zambezi	warthog	2351	±614	1737	-	2965	26%	506	9	0.130	89495
Kavango Zambezi	waterbuck	141	±123	18	-	264	87%	38	6	0.008	3740
Kavango Zambezi	wildebeest	434	±270	164	-	704	62%	84	140	0.024	18117
Kavango Zambezi	zebra	12597	±5824	6773	-	18421	46%	1351	892	0.698	8299332
Livestock											
Kavango Zambezi	cattle	145314	±41189	104125	-	186503	28%	7448	921	8.047	401884034
Kavango Zambezi	donkey	311	±747	9	-	1058	240%	9	0	0.017	64687
Kavango Zambezi	horse	Not observed in the sample						0	0		
Kavango Zambezi	shoat	11212	±7668	3544	-	18880	68%	496	43	0.621	13266065

Table 3.11: Population estimates and associated statistics for all species in the Khaudum Nyae-Nyae superstratum (Namibia).

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Khaudum Nyae-Nyae	all elephants	8745	±3009	5736	-	11754	34%	762	1105	0.478	2241625
Khaudum Nyae-Nyae	elephant bulls	2037	±741	1296	-	2778	36%	156	281	0.111	137210
Khaudum Nyae-Nyae	elephant family	6708	±2884	3824	-	9592	43%	606	824	0.366	2050449
Khaudum Nyae-Nyae	all elephant carcasses	185	±89	96	-	274	48%	15	1	0.010	1949
Khaudum Nyae-Nyae	C1-2 elephant carcasses	32	±35	3	-	67	109%	3	0	0.002	297
Khaudum Nyae-Nyae	C3-4 elephant carcasses	154	±83	71	-	237	54%	12	1	0.008	1686
Khaudum Nyae-Nyae	elephant carcass one	12	±25	1	-	37	208%	1	0	0.001	138
Khaudum Nyae-Nyae	elephant carcass two	19	±27	2	-	46	142%	2	0	0.001	159
Khaudum Nyae-Nyae	elephant carcass three	87	±64	23	-	151	74%	7	1	0.005	993
Khaudum Nyae-Nyae	elephant carcass four	67	±60	7	-	127	90%	5	0	0.004	859
Wildlife											
Khaudum Nyae-Nyae	baboon	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	buffalo	81	±150	6	-	231	185%	6	42	0.004	4783
Khaudum Nyae-Nyae	bushbuck	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	bushpig	94	±191	3	-	285	203%	3	0	0.005	7537
Khaudum Nyae-Nyae	duiker	1135	±450	685	-	1585	40%	52	1	0.062	46846
Khaudum Nyae-Nyae	eland	1545	±1634	78	-	3179	106%	78	39	0.084	628436
Khaudum Nyae-Nyae	giraffe	604	±560	45	-	1164	93%	45	12	0.033	73598
Khaudum Nyae-Nyae	grysbok	10	±19	1	-	29	190%	1	0	0.001	84
Khaudum Nyae-Nyae	hartebeest	Not observed in the sample						0	2		
Khaudum Nyae-Nyae	hippopotamus	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	impala	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	klipspringer	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	kudu	838	±392	446	-	1230	47%	61	26	0.046	36894
Khaudum Nyae-Nyae	oribi	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	oryx	1582	±527	1055	-	2109	33%	129	66	0.086	70359
Khaudum Nyae-Nyae	ostrich	759	±378	381	-	1137	50%	54	55	0.041	34955
Khaudum Nyae-Nyae	puku	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	red lechwe	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	reedbuck	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	roan	937	±586	351	-	1523	63%	92	1	0.051	85600
Khaudum Nyae-Nyae	sable	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	sitatunga	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	springbok	19	±39	2	-	58	205%	2	0	0.001	338
Khaudum Nyae-Nyae	tsessebe	Not observed in the sample						0	15		
Khaudum Nyae-Nyae	warthog	836	±682	154	-	1518	82%	77	30	0.046	108492
Khaudum Nyae-Nyae	waterbuck	Not observed in the sample						0	0		
Khaudum Nyae-Nyae	wildebeest	2642	±1725	917	-	4367	65%	243	227	0.144	730684
Khaudum Nyae-Nyae	zebra	144	±195	15	-	339	135%	15	6	0.008	9164
Livestock											
Khaudum Nyae-Nyae	cattle	12186	±7141	5045	-	19327	59%	559	69	0.666	12174205
Khaudum Nyae-Nyae	donkey	306	±314	13	-	620	103%	13	4	0.017	22191
Khaudum Nyae-Nyae	horse	104	±142	5	-	246	137%	5	8	0.006	4499
Khaudum Nyae-Nyae	shoat	2427	±1965	462	-	4392	81%	118	0	0.133	887705

Table 3.12: Population estimates and associated statistics for all species in the Zambia portion of the KAZA TFCA survey area.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Zambia	all elephants	3840	±1398	2442	-	5238	36%	385	475	0.052	492051
Zambia	elephant bulls	359	±162	197	-	521	45%	36	23	0.005	6611
Zambia	elephant family	3481	±1371	2110	-	4852	39%	349	452	0.047	471802
Zambia	all elephant carcasses	137	±77	60	-	214	56%	13	4	0.002	1520
Zambia	C1-2 elephant carcasses	10	±19	1	-	29	190%	1	0	0.000	84
Zambia	C3-4 elephant carcasses	127	±71	56	-	198	56%	12	4	0.002	1270
Zambia	elephant carcass one	Not observed in the sample						0	0		
Zambia	elephant carcass two	10	±19	1	-	29	190%	1	0	0.000	84
Zambia	elephant carcass three	119	±69	50	-	188	58%	11	2	0.002	1210
Zambia	elephant carcass four	8	±16	1	-	24	200%	1	2	0.000	60
Wildlife											
Zambia	baboon	Not observed in the sample						0	0		
Zambia	buffalo	4158	±2840	1318	-	6998	68%	370	2978	0.056	1979019
Zambia	bushbuck	315	±153	162	-	468	49%	29	0	0.004	5938
Zambia	bushpig	625	±359	266	-	984	57%	61	11	0.008	30881
Zambia	duiker	5483	±762	4721	-	6245	14%	487	53	0.074	147116
Zambia	eland	1061	±1088	101	-	2149	103%	101	223	0.014	290981
Zambia	giraffe	542	±484	58	-	1026	89%	42	70	0.007	53433
Zambia	grysbok	10	±20	1	-	30	200%	1	0	0.000	94
Zambia	hartebeest	10905	±2538	8367	-	13443	23%	1052	843	0.148	1659192
Zambia	hippopotamus	3819	±1586	2233	-	5405	42%	376	154	0.052	644211
Zambia	impala	14510	±6437	8073	-	20947	44%	1462	1912	0.197	10297511
Zambia	klipspringer	Not observed in the sample						0	0		
Zambia	kudu	2310	±709	1601	-	3019	31%	226	130	0.031	128731
Zambia	oribi	69	±78	7	-	147	113%	7	4	0.001	1553
Zambia	oryx	Not observed in the sample						0	0		
Zambia	ostrich	Not observed in the sample						0	0		
Zambia	puku	13632	±4940	8692	-	18572	36%	1378	1455	0.185	6161864
Zambia	red lechwe	22826	±5184	17642	-	28010	23%	5745	3578	0.309	6507385
Zambia	reedbuck	865	±332	533	-	1197	38%	78	12	0.012	28341
Zambia	roan	3134	±1397	1737	-	4531	45%	303	440	0.042	491748
Zambia	sable	18706	±4846	13860	-	23552	26%	1602	2484	0.253	5813595
Zambia	sitatunga	30	±42	3	-	72	140%	3	0	0.000	403
Zambia	springbok	Not observed in the sample						0	0		
Zambia	tsessebe	16	±34	1	-	50	213%	1	2	0.000	247
Zambia	warthog	11398	±1682	9716	-	13080	15%	1126	371	0.154	727615
Zambia	waterbuck	2774	±988	1786	-	3762	36%	277	157	0.038	247133
Zambia	wildebeest	2628	±1565	1063	-	4193	60%	266	810	0.036	602610
Zambia	zebra	1539	±638	901	-	2177	41%	157	304	0.021	104277
Livestock											
Zambia	cattle	108083	±17266	90817	-	125349	16%	5959	3254	1.464	73183368
Zambia	donkey	410	±319	91	-	729	78%	22	0	0.006	21143
Zambia	horse	Not observed in the sample						0	0		
Zambia	shoat	29473	±7919	21554	-	37392	27%	1712	580	0.399	15384836

Table 3.13: Population estimates and associated statistics for all species in the Kafue superstratum (Zambia).

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Kafue	all elephants	3840	±1398	2442	-	5238	36%	385	475	0.060	492051
Kafue	elephant bulls	359	±162	197	-	521	45%	36	23	0.006	6611
Kafue	elephant family	3481	±1371	2110	-	4852	39%	349	452	0.054	471802
Kafue	all elephant carcasses	129	±76	53	-	205	59%	12	4	0.002	1461
Kafue	C1-2 elephant carcasses	10	±19	1	-	29	190%	1	0	0.000	84
Kafue	C3-4 elephant carcasses	119	±69	50	-	188	58%	11	4	0.002	1210
Kafue	elephant carcass one	Not observed in the sample						0	0		
Kafue	elephant carcass two	10	±19	1	-	29	190%	1	0	0.000	84
Kafue	elephant carcass three	119	±69	50	-	188	58%	11	2	0.002	1210
Kafue	elephant carcass four	Not observed in the sample						0	2		
Wildlife											
Kafue	baboon	Not observed in the sample						0	0		
Kafue	buffalo	4118	±2839	1279	-	6957	69%	365	2728	0.064	1977550
Kafue	bushbuck	299	±150	149	-	449	50%	28	0	0.005	5705
Kafue	bushpig	601	±357	244	-	958	59%	59	11	0.009	30552
Kafue	duiker	1973	±369	1604	-	2342	19%	173	5	0.031	34878
Kafue	eland	795	±1044	80	-	1839	131%	80	94	0.012	265062
Kafue	giraffe	Not observed in the sample						0	0		
Kafue	grysbok	10	±20	1	-	30	200%	1	0	0.000	94
Kafue	hartebeest	10905	±2538	8367	-	13443	23%	1052	843	0.171	1659192
Kafue	hippopotamus	3549	±1540	2009	-	5089	43%	359	148	0.056	606737
Kafue	impala	14510	±6437	8073	-	20947	44%	1462	1912	0.227	10297511
Kafue	klipspringer	Not observed in the sample						0	0		
Kafue	kudu	1744	±626	1118	-	2370	36%	165	95	0.027	99894
Kafue	oribi	69	±78	7	-	147	113%	7	4	0.001	1553
Kafue	oryx	Not observed in the sample						0	0		
Kafue	ostrich	Not observed in the sample						0	0		
Kafue	puku	13632	±4940	8692	-	18572	36%	1378	1455	0.213	6161864
Kafue	red lechwe	22826	±5184	17642	-	28010	23%	5745	3578	0.357	6507385
Kafue	reedbuck	865	±332	533	-	1197	38%	78	12	0.014	28341
Kafue	roan	2839	±1380	1459	-	4219	49%	269	424	0.044	478792
Kafue	sable	17557	±4614	12943	-	22171	26%	1510	2324	0.275	5218396
Kafue	sitatunga	30	±42	3	-	72	140%	3	0	0.000	403
Kafue	springbok	Not observed in the sample						0	0		
Kafue	tsessebe	Not observed in the sample						0	0		
Kafue	warthog	11223	±1677	9546	-	12900	15%	1109	367	0.176	723171
Kafue	waterbuck	2774	±988	1786	-	3762	36%	277	157	0.043	247133
Kafue	wildebeest	2294	±1533	761	-	3827	67%	233	731	0.036	574723
Kafue	zebra	1491	±632	859	-	2123	42%	151	274	0.023	102150
Livestock											
Kafue	cattle	96688	±16452	80236	-	113140	17%	5167	2737	1.514	65541528
Kafue	donkey	410	±319	91	-	729	78%	22	0	0.006	21143
Kafue	horse	Not observed in the sample						0	0		
Kafue	shoat	28806	±7872	20934	-	36678	27%	1665	568	0.451	15176647

Table 3.14: Population estimates and associated statistics for all species in the Sioma superstratum (Zambia).

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Sioma	all elephants	Not observed in the sample						0	0		
Sioma	elephant bulls	Not observed in the sample						0	0		
Sioma	elephant family	Not observed in the sample						0	0		
Sioma	all elephant carcasses	8	±16	1	-	24	200%	1	0	0.001	60
Sioma	C1-2 elephant carcasses	Not observed in the sample						0	0		
Sioma	C3-4 elephant carcasses	8	±16	1	-	24	200%	1	0	0.001	60
Sioma	elephant carcass one	Not observed in the sample						0	0		
Sioma	elephant carcass two	Not observed in the sample						0	0		
Sioma	elephant carcass three	Not observed in the sample						0	0		
Sioma	elephant carcass four	8	±16	1	-	24	200%	1	0	0.001	60
Wildlife											
Sioma	baboon	Not observed in the sample						0	0		
Sioma	buffalo	40	±79	5	-	119	198%	5	250	0.004	1469
Sioma	bushbuck	16	±33	1	-	49	206%	1	0	0.002	233
Sioma	bushpig	24	±38	2	-	62	158%	2	0	0.002	330
Sioma	duiker	3509	±672	2837	-	4181	19%	314	48	0.353	112239
Sioma	eland	265	±338	21	-	603	128%	21	129	0.027	25920
Sioma	giraffe	542	±484	58	-	1026	89%	42	70	0.054	53433
Sioma	grysbok	Not observed in the sample						0	0		
Sioma	hartebeest	Not observed in the sample						0	0		
Sioma	hippopotamus	269	±410	6	-	679	152%	17	6	0.027	37474
Sioma	impala	Not observed in the sample						0	0		
Sioma	klipspringer	Not observed in the sample						0	0		
Sioma	kudu	566	±343	223	-	909	61%	61	35	0.057	28837
Sioma	oribi	Not observed in the sample						0	0		
Sioma	oryx	Not observed in the sample						0	0		
Sioma	ostrich	Not observed in the sample						0	0		
Sioma	puku	Not observed in the sample						0	0		
Sioma	red lechwe	Not observed in the sample						0	0		
Sioma	reedbuck	Not observed in the sample						0	0		
Sioma	roan	295	±228	67	-	523	77%	34	16	0.030	12956
Sioma	sable	1149	±1670	92	-	2819	145%	92	160	0.115	595199
Sioma	sitatunga	Not observed in the sample						0	0		
Sioma	springbok	Not observed in the sample						0	0		
Sioma	tsessebe	16	±34	1	-	50	213%	1	2	0.002	247
Sioma	warthog	175	±134	41	-	309	77%	17	4	0.018	4444
Sioma	waterbuck	Not observed in the sample						0	0		
Sioma	wildebeest	334	±342	33	-	676	102%	33	79	0.034	27888
Sioma	zebra	48	±95	6	-	143	198%	6	30	0.005	2127
Livestock											
Sioma	cattle	11395	±5613	5782	-	17008	49%	792	517	1.145	7641841
Sioma	donkey	Not observed in the sample						0	0		
Sioma	horse	Not observed in the sample						0	0		
Sioma	shoat	668	±958	47	-	1626	143%	47	12	0.067	208189

Table 3.15: Population estimates and associated statistics for all species in the Zimbabwe portion of the KAZA TFCA survey area.

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Zimbabwe	all elephants	65028	±9457	55571	-	74485	15%	7161	11569	1.599	21722971
Zimbabwe	elephant bulls	7606	±1217	6389	-	8823	16%	804	1495	0.187	377077
Zimbabwe	elephant family	57422	±9220	48202	-	66642	16%	6357	10074	1.412	20591615
Zimbabwe	all elephant carcasses	5166	±612	4554	-	5778	12%	552	193	0.127	93958
Zimbabwe	C1-2 elephant carcasses	64	±54	10	-	118	84%	7	3	0.002	697
Zimbabwe	C3-4 elephant carcasses	5102	±609	4493	-	5711	12%	545	190	0.125	92795
Zimbabwe	elephant carcass one	24	±29	3	-	53	121%	3	1	0.001	202
Zimbabwe	elephant carcass two	40	±47	4	-	87	118%	4	2	0.001	504
Zimbabwe	elephant carcass three	2194	±402	1792	-	2596	18%	214	106	0.054	40347
Zimbabwe	elephant carcass four	2908	±382	2526	-	3290	13%	331	84	0.072	36795
Wildlife											
Zimbabwe	baboon	861	±583	278	-	1444	68%	84	8	0.021	81129
Zimbabwe	buffalo	12878	±9165	3713	-	22043	71%	1404	1886	0.317	19002555
Zimbabwe	bushbuck	120	±70	50	-	190	58%	18	0	0.003	1189
Zimbabwe	bushpig	Not observed in the sample						0	0		
Zimbabwe	duiker	250	±121	129	-	371	48%	25	0	0.006	3601
Zimbabwe	eland	204	±166	38	-	370	81%	31	0	0.005	6896
Zimbabwe	giraffe	1501	±493	1008	-	1994	33%	149	93	0.037	61298
Zimbabwe	grysbok	Not observed in the sample						0	0		
Zimbabwe	hartebeest	Not observed in the sample						0	0		
Zimbabwe	hippopotamus	1541	±1120	421	-	2661	73%	179	21	0.038	301145
Zimbabwe	impala	23898	±7460	16438	-	31358	31%	3179	190	0.588	13487099
Zimbabwe	klipspringer	40	±60	4	-	100	150%	4	0	0.001	816
Zimbabwe	kudu	3154	±927	2227	-	4081	29%	344	49	0.078	210556
Zimbabwe	oribi	Not observed in the sample						0	0		
Zimbabwe	oryx	96	±90	7	-	186	94%	7	0	0.002	1954
Zimbabwe	ostrich	117	±123	12	-	240	105%	12	4	0.003	3195
Zimbabwe	puku	Not observed in the sample						0	0		
Zimbabwe	red lechwe	Not observed in the sample						0	0		
Zimbabwe	reedbuck	186	±242	24	-	428	130%	24	0	0.005	12894
Zimbabwe	roan	436	±402	39	-	838	92%	39	23	0.011	35659
Zimbabwe	sable	2127	±1343	784	-	3470	63%	179	98	0.052	415968
Zimbabwe	sitatunga	Not observed in the sample						0	0		
Zimbabwe	springbok	Not observed in the sample						0	0		
Zimbabwe	tsessebe	Not observed in the sample						0	0		
Zimbabwe	warthog	1213	±451	762	-	1664	37%	148	5	0.030	45448
Zimbabwe	waterbuck	1307	±710	597	-	2017	54%	167	18	0.032	119065
Zimbabwe	wildebeest	171	±187	24	-	358	109%	24	200	0.004	8289
Zimbabwe	zebra	5772	±2867	2905	-	8639	50%	623	156	0.142	1776898
Livestock											
Zimbabwe	cattle	93471	±12780	80691	-	106251	14%	4672	200	2.299	38843621
Zimbabwe	donkey	4847	±2135	2712	-	6982	44%	252	12	0.119	1022053
Zimbabwe	horse	Not observed in the sample						0	0		
Zimbabwe	shoat	72755	±9682	63073	-	82437	13%	3848	10	1.789	23213759

Table 3.16: Summary of population estimates and associated statistics for all species in the North-West Matabeleland superstratum (Zimbabwe).

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km^{-2})	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
North-West Matabeleland	all elephants	61531	±9408	52123	-	70939	15%	6643	11466	2.457	21459924
North-West Matabeleland	elephant bulls	7155	±1195	5960	-	8350	17%	737	1482	0.286	363285
North-West Matabeleland	elephant family	54376	±9173	45203	-	63549	17%	5906	9984	2.171	20346770
North-West Matabeleland	all elephant carcasses	4427	±593	3834	-	5020	13%	443	190	0.177	87581
North-West Matabeleland	C1-2 elephant carcasses	64	±54	10	-	118	84%	7	3	0.003	697
North-West Matabeleland	C3-4 elephant carcasses	4363	±589	3774	-	4952	13%	436	187	0.174	86418
North-West Matabeleland	elephant carcass one	24	±29	3	-	53	121%	3	1	0.001	202
North-West Matabeleland	elephant carcass two	40	±47	4	-	87	118%	4	2	0.002	504
North-West Matabeleland	elephant carcass three	2087	±399	1688	-	2486	19%	194	106	0.083	39588
North-West Matabeleland	elephant carcass four	2275	±357	1918	-	2632	16%	242	81	0.091	31791
Wildlife											
North-West Matabeleland	baboon	544	±527	50	-	1071	97%	50	8	0.022	63195
North-West Matabeleland	buffalo	9878	±8967	1005	-	18845	91%	1005	1672	0.394	17840316
North-West Matabeleland	bushbuck	24	±32	5	-	56	133%	5	0	0.001	249
North-West Matabeleland	bushpig	Not observed in the sample						0	0		
North-West Matabeleland	duiker	215	±117	98	-	332	54%	20	0	0.009	3324
North-West Matabeleland	eland	180	±164	27	-	344	91%	27	0	0.007	6656
North-West Matabeleland	giraffe	1501	±493	1008	-	1994	33%	149	93	0.060	61298
North-West Matabeleland	grysbok	Not observed in the sample						0	0		
North-West Matabeleland	hartebeest	Not observed in the sample						0	0		
North-West Matabeleland	hippopotamus	531	±601	48	-	1132	113%	48	4	0.021	70441
North-West Matabeleland	impala	5882	±2010	3872	-	7892	34%	646	102	0.235	998228
North-West Matabeleland	klipspringer	40	±60	4	-	100	150%	4	0	0.002	816
North-West Matabeleland	kudu	3012	±924	2088	-	3936	31%	322	49	0.120	209139
North-West Matabeleland	oribi	Not observed in the sample						0	0		
North-West Matabeleland	oryx	96	±90	7	-	186	94%	7	0	0.004	1954
North-West Matabeleland	ostrich	117	±123	12	-	240	105%	12	4	0.005	3195
North-West Matabeleland	puku	Not observed in the sample						0	0		
North-West Matabeleland	red lechwe	Not observed in the sample						0	0		
North-West Matabeleland	reedbuck	186	±242	24	-	428	130%	24	0	0.007	12894
North-West Matabeleland	roan	436	±402	39	-	838	92%	39	23	0.017	35659
North-West Matabeleland	sable	2112	±1343	769	-	3455	64%	177	76	0.084	415867
North-West Matabeleland	sitatunga	Not observed in the sample						0	0		
North-West Matabeleland	springbok	Not observed in the sample						0	0		
North-West Matabeleland	tsessebe	Not observed in the sample						0	0		
North-West Matabeleland	warthog	896	±423	473	-	1319	47%	99	5	0.036	36830
North-West Matabeleland	waterbuck	992	±661	331	-	1653	67%	114	18	0.040	99184
North-West Matabeleland	wildebeest	171	±187	24	-	358	109%	24	200	0.007	8289
North-West Matabeleland	zebra	4933	±2853	2080	-	7786	58%	501	147	0.197	1747900
Livestock											
North-West Matabeleland	cattle	9170	±3727	5443	-	12897	41%	493	200	0.366	3229177
North-West Matabeleland	donkey	2203	±1941	262	-	4144	88%	99	12	0.088	742310
North-West Matabeleland	horse	Not observed in the sample						0	0		
North-West Matabeleland	shoat	3655	±2331	1324	-	5986	64%	183	10	0.146	1161036

Table 3.17: Summary of population estimates and associated statistics for all species in the Sebungwe superstratum (Zimbabwe).

Zone	Species	Population Estimate	CI	95% Confidence Range			PRP	No Seen		Density (km-2)	Variance
				Lower CL		Upper CL		In	Out		
Elephant											
Sebungwe	all elephants	3498	±1020	2478	-	4518	29%	518	103	0.224	263046
Sebungwe	elephant bulls	451	±244	207	-	695	54%	67	13	0.029	13793
Sebungwe	elephant family	3046	±984	2062	-	4030	32%	451	90	0.195	244845
Sebungwe	all elephant carcasses	740	±159	581	-	899	21%	109	3	0.047	6377
Sebungwe	C1-2 elephant carcasses	Not observed in the sample						0	0		
Sebungwe	C3-4 elephant carcasses	740	±159	581	-	899	21%	109	3	0.047	6377
Sebungwe	elephant carcass one	Not observed in the sample						0	0		
Sebungwe	elephant carcass two	Not observed in the sample						0	0		
Sebungwe	elephant carcass three	106	±59	47	-	165	56%	20	0	0.007	759
Sebungwe	elephant carcass four	633	±140	493	-	773	22%	89	3	0.041	5004
Wildlife											
Sebungwe	baboon	317	±283	34	-	600	89%	34	0	0.020	17934
Sebungwe	buffalo	3000	±2175	825	-	5175	73%	399	214	0.192	1162240
Sebungwe	bushbuck	97	±63	34	-	160	65%	13	0	0.006	941
Sebungwe	bushpig	Not observed in the sample						0	0		
Sebungwe	duiker	35	±33	5	-	68	94%	5	0	0.002	277
Sebungwe	eland	24	±32	4	-	56	133%	4	0	0.002	240
Sebungwe	giraffe	Not observed in the sample						0	0		
Sebungwe	grysbok	Not observed in the sample						0	0		
Sebungwe	hartebeest	Not observed in the sample						0	0		
Sebungwe	hippopotamus	1009	±996	131	-	2005	99%	131	17	0.065	230704
Sebungwe	impala	18016	±7222	10794	-	25238	40%	2533	88	1.153	12488871
Sebungwe	klipspringer	Not observed in the sample						0	0		
Sebungwe	kudu	142	±76	66	-	218	54%	22	0	0.009	1417
Sebungwe	oribi	Not observed in the sample						0	0		
Sebungwe	oryx	Not observed in the sample						0	0		
Sebungwe	ostrich	Not observed in the sample						0	0		
Sebungwe	puku	Not observed in the sample						0	0		
Sebungwe	red lechwe	Not observed in the sample						0	0		
Sebungwe	reedbuck	Not observed in the sample						0	0		
Sebungwe	roan	Not observed in the sample						0	0		
Sebungwe	sable	15	±21	2	-	36	140%	2	22	0.001	101
Sebungwe	sitatunga	Not observed in the sample						0	0		
Sebungwe	springbok	Not observed in the sample						0	0		
Sebungwe	tsessebe	Not observed in the sample						0	0		
Sebungwe	warthog	317	±185	132	-	502	58%	49	0	0.020	8618
Sebungwe	waterbuck	316	±286	53	-	602	91%	53	0	0.020	19880
Sebungwe	wildebeest	Not observed in the sample						0	0		
Sebungwe	zebra	839	±340	499	-	1179	41%	122	9	0.054	28997
Livestock											
Sebungwe	cattle	84301	±12340	71961	-	96641	15%	4179	0	5.397	35614445
Sebungwe	donkey	2644	±1080	1564	-	3724	41%	153	0	0.169	279743
Sebungwe	horse	Not observed in the sample						0	0		
Sebungwe	shoat	69100	±9460	59640	-	78560	14%	3665	0	4.424	22052723

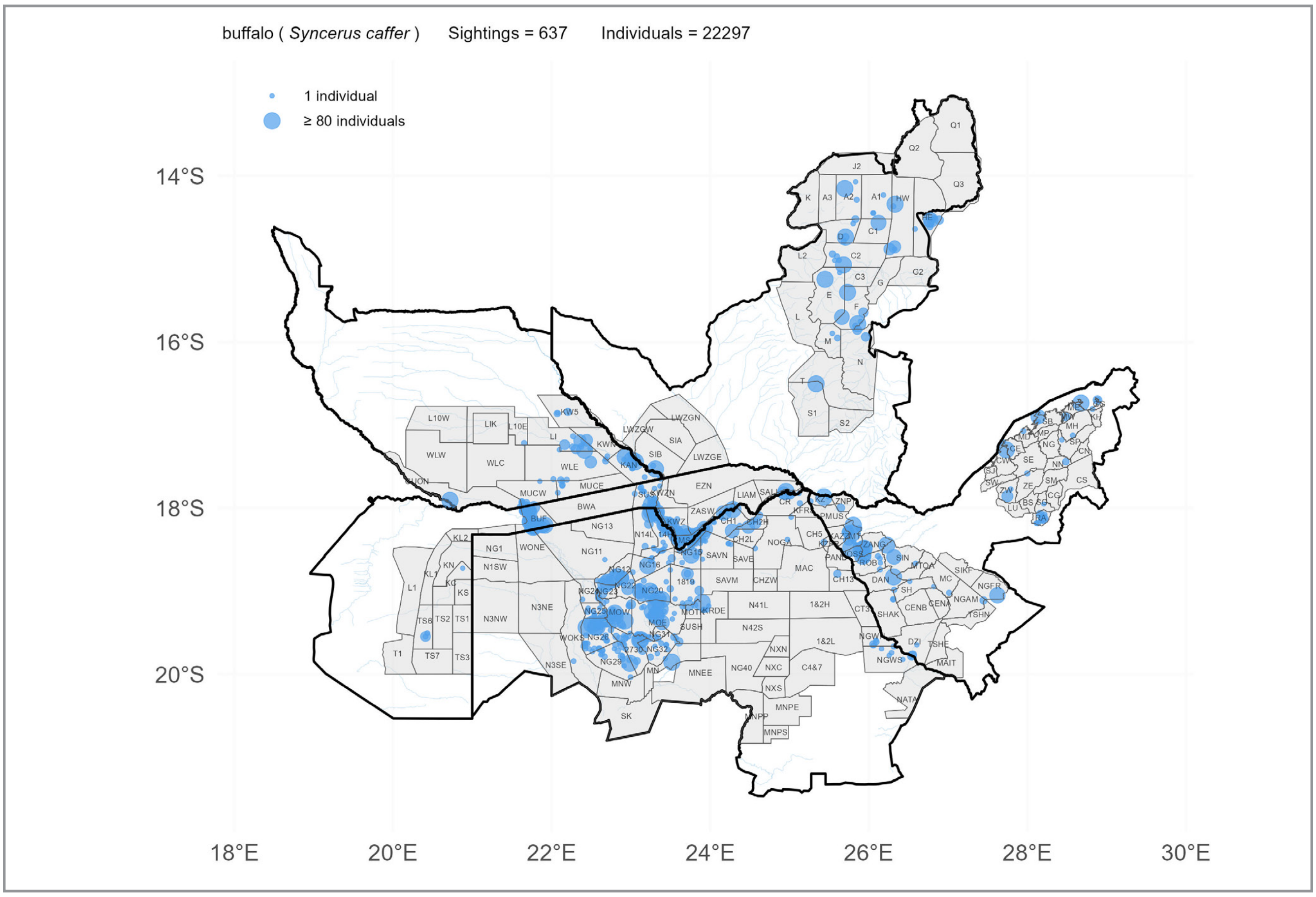


Figure 3.14: Spatial distribution of buffalo observations in the KAZA TFCA survey area during the 2022 survey.

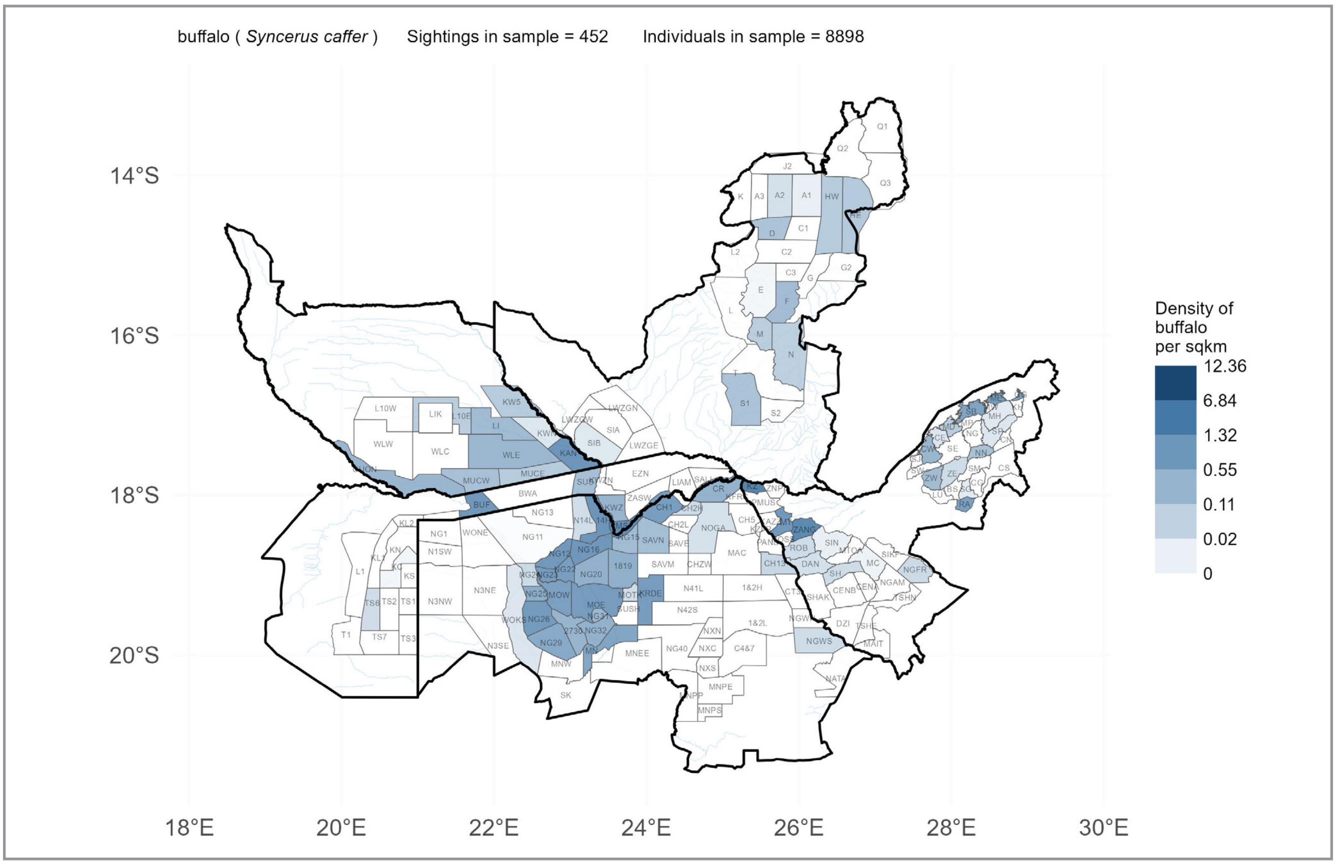


Figure 3.15: Estimated density of buffalo in the KAZA TFCA survey area during the 2022 survey.

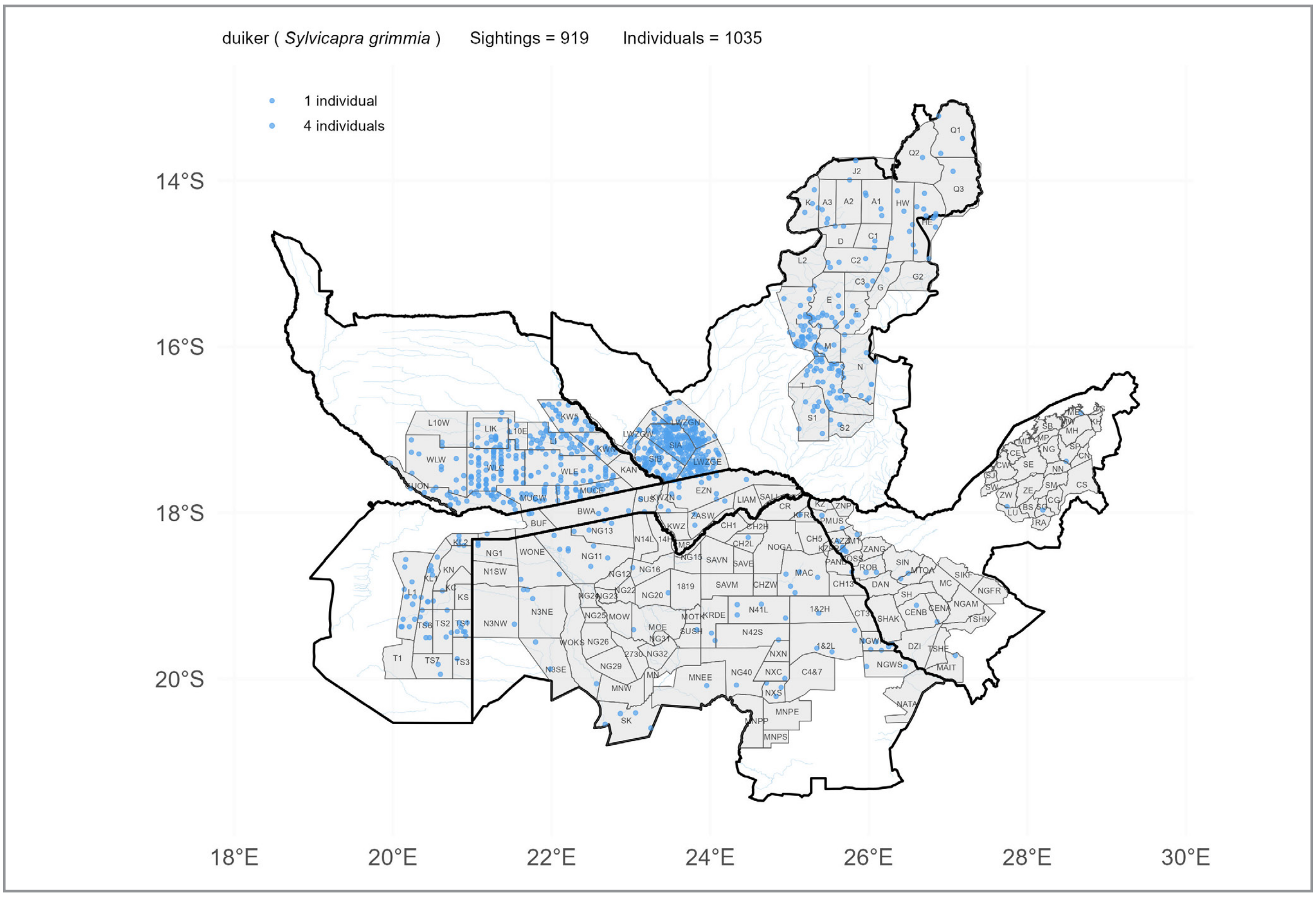


Figure 3.16: Spatial distribution of duiker observations in the KAZA TFCA survey area during the 2022 survey.

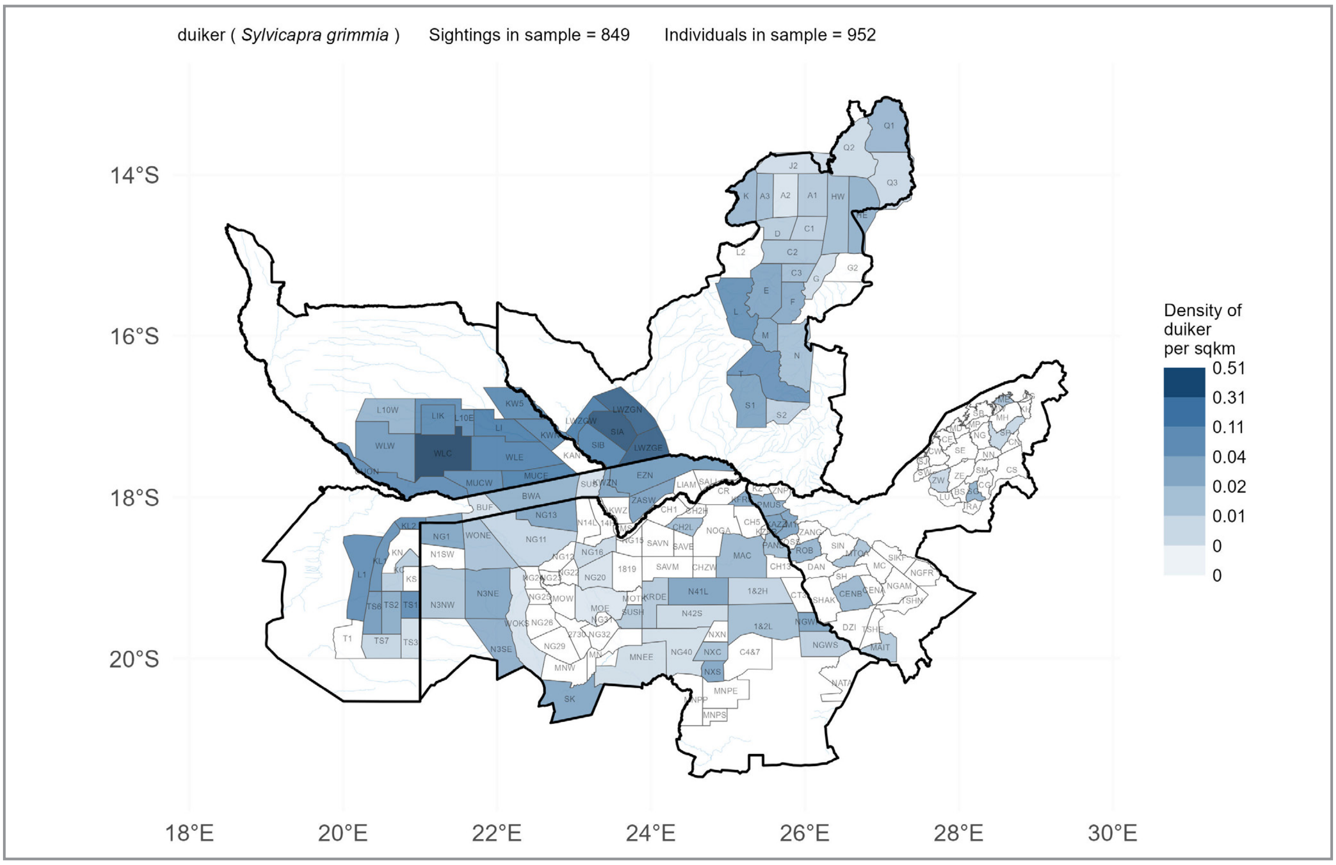


Figure 3.17: Estimated density of duiker in the KAZA TFCA survey area during the 2022 survey.

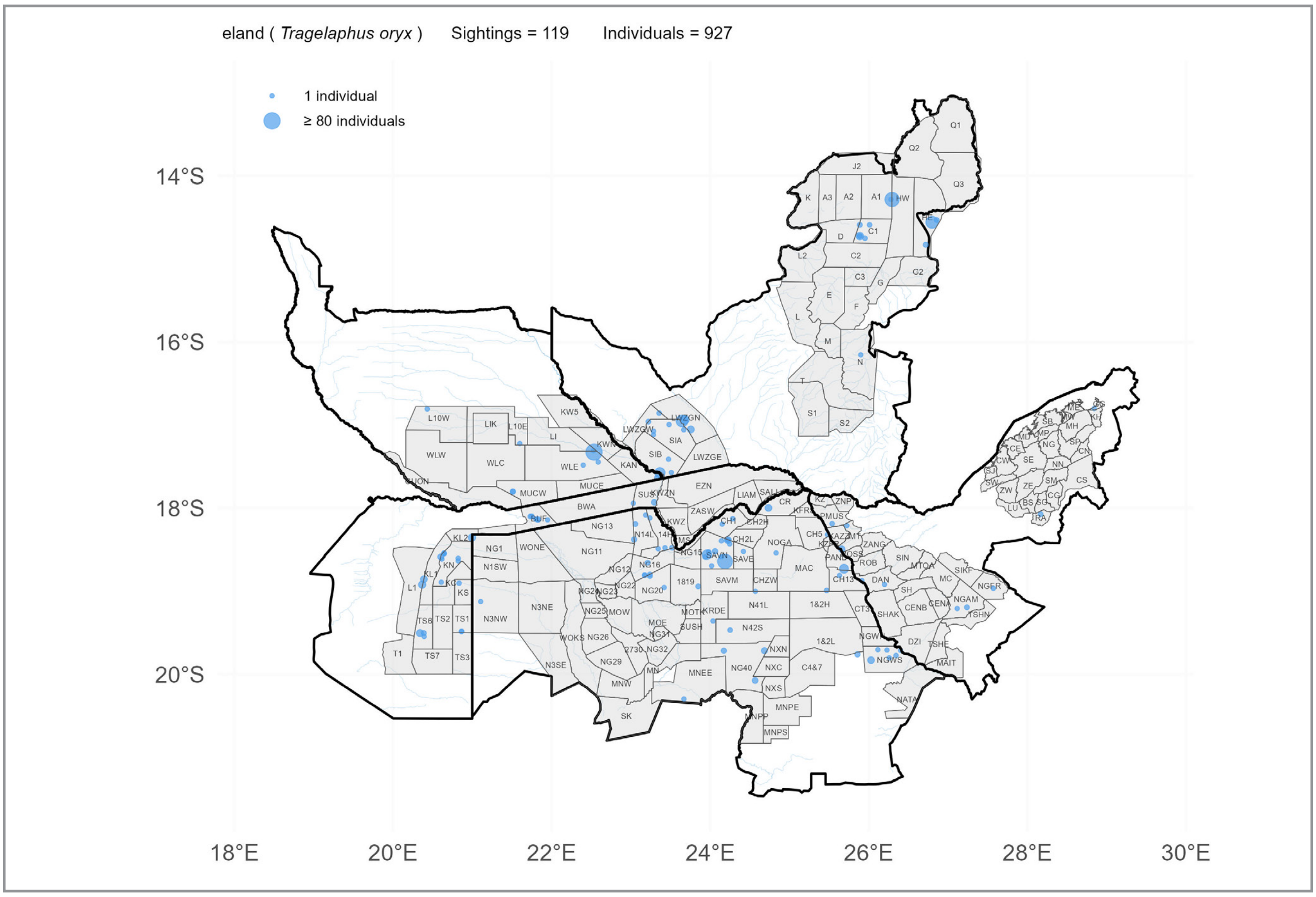


Figure 3.18: Spatial distribution of eland observations in the KAZA TFCA survey area during the 2022 survey.

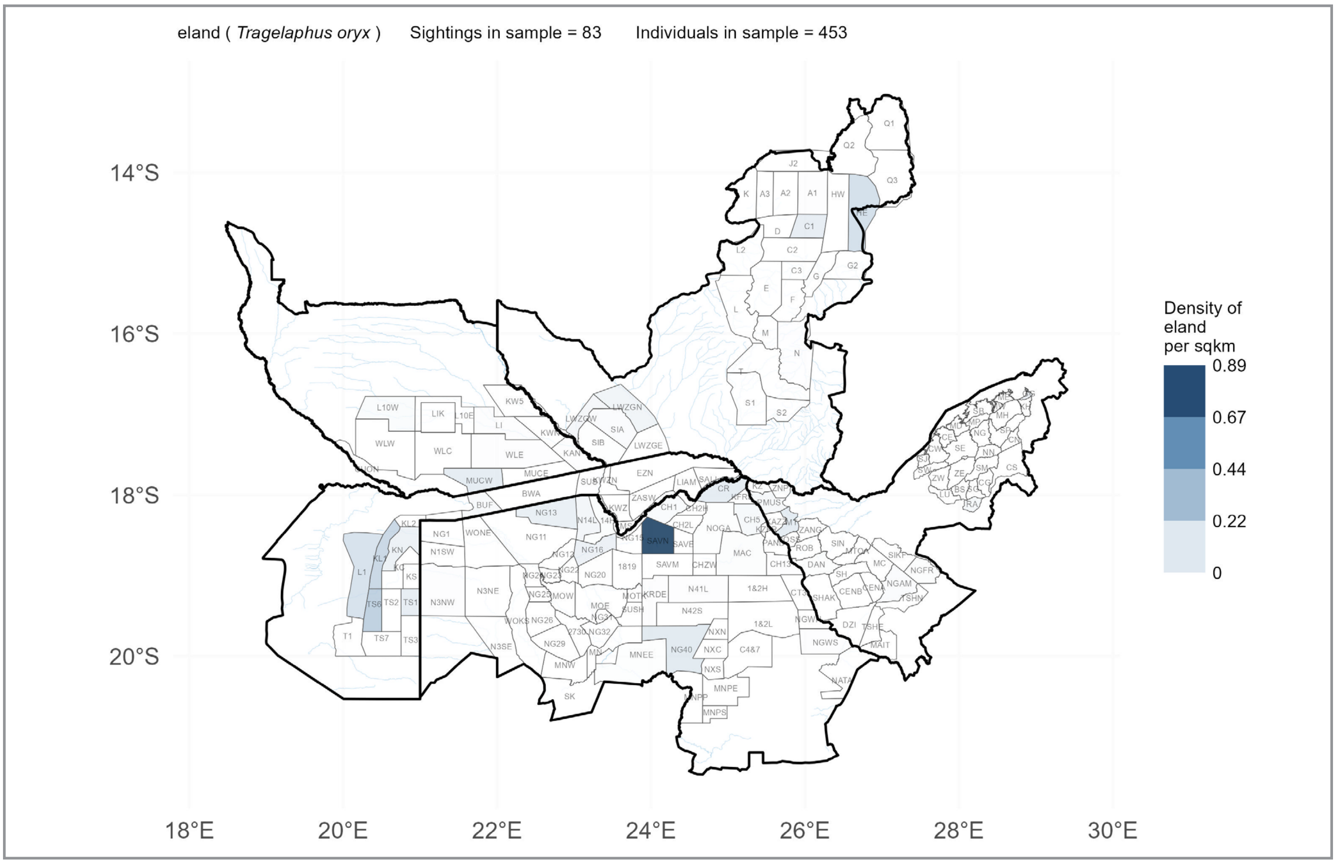


Figure 3.19: Estimated density of eland in the KAZA TFCA survey area during the 2022 survey.

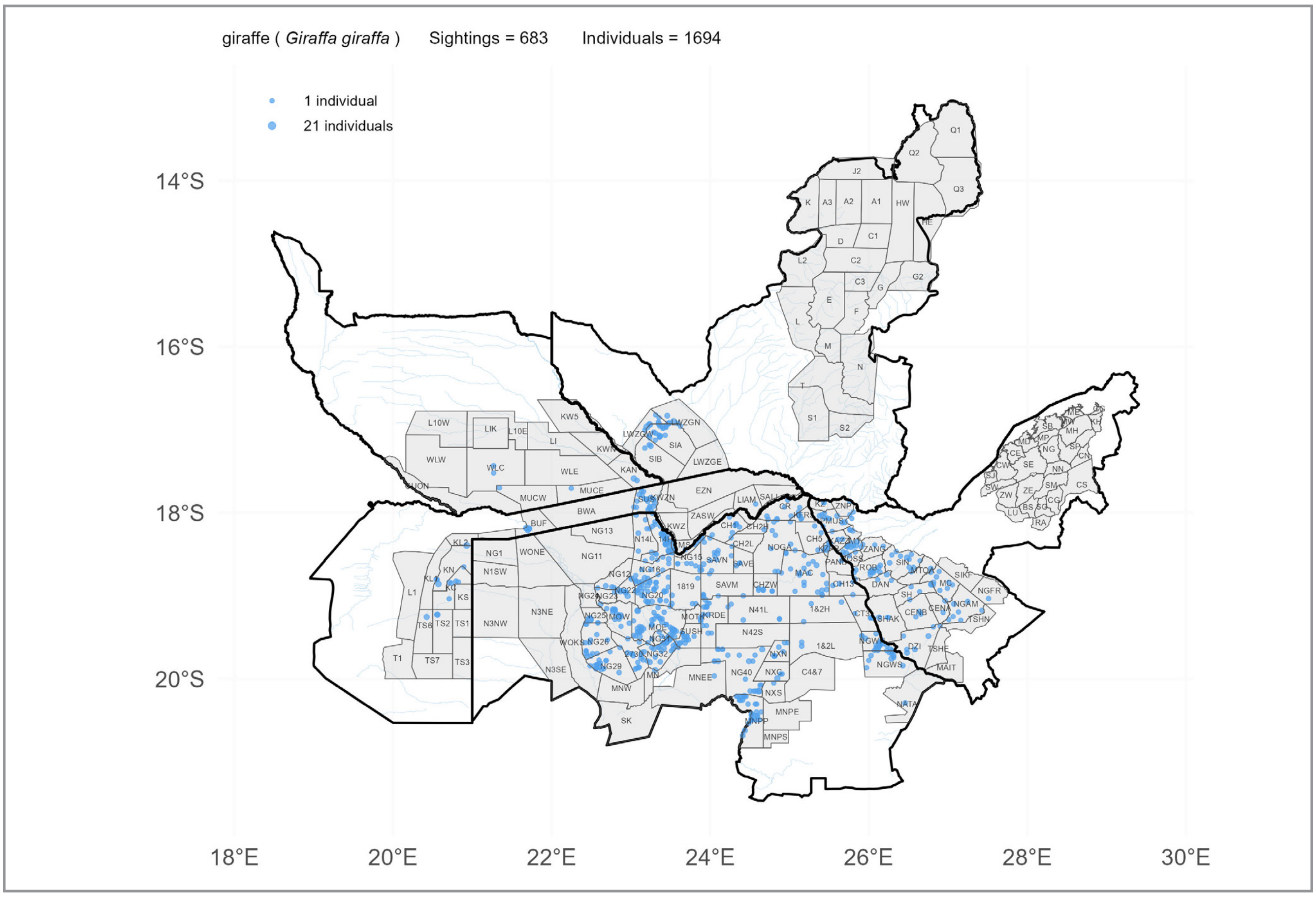


Figure 3.20: Spatial distribution of giraffe observations in the KAZA TFCA survey area during the 2022 survey.

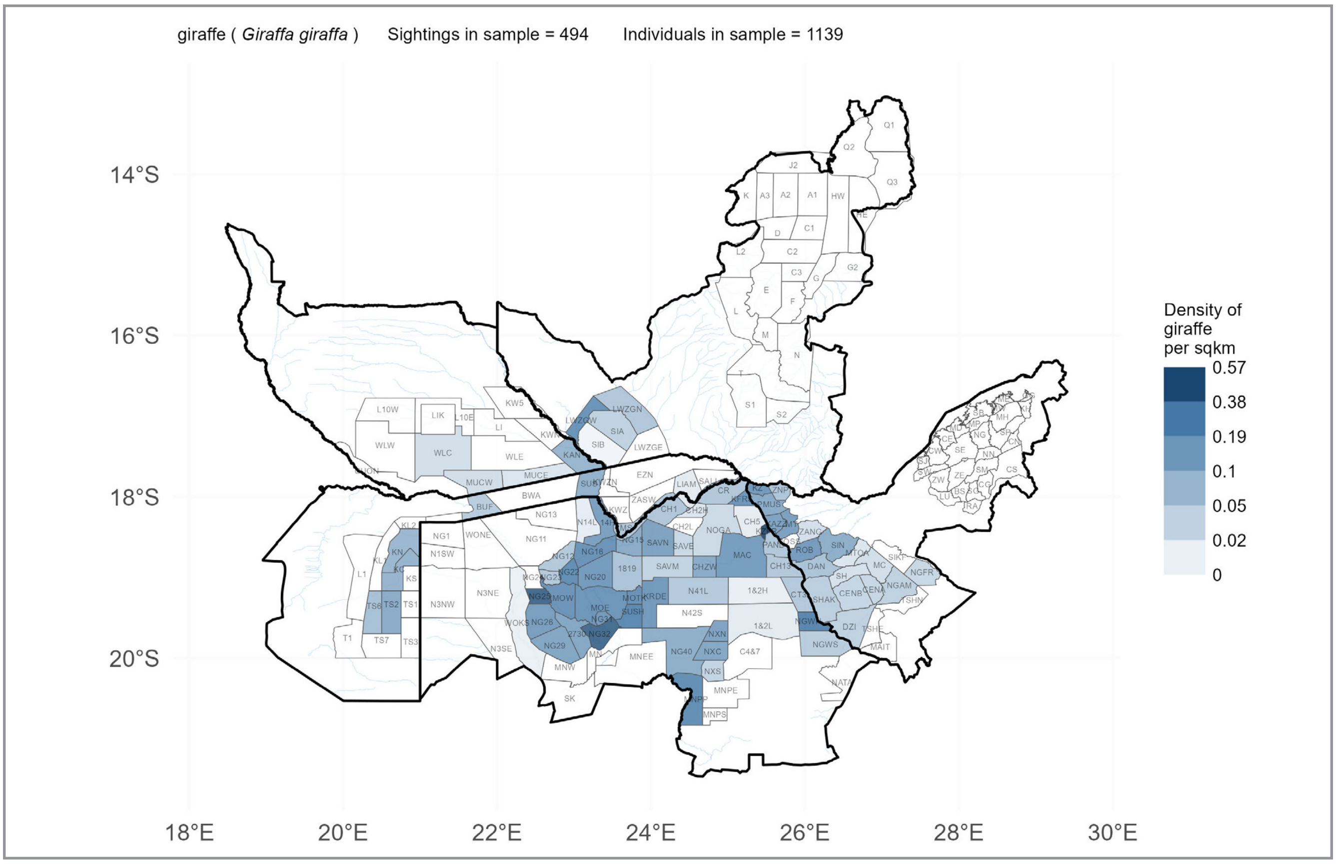


Figure 3.21: Estimated density of giraffe in the KAZA TFCA survey area during the 2022 survey.

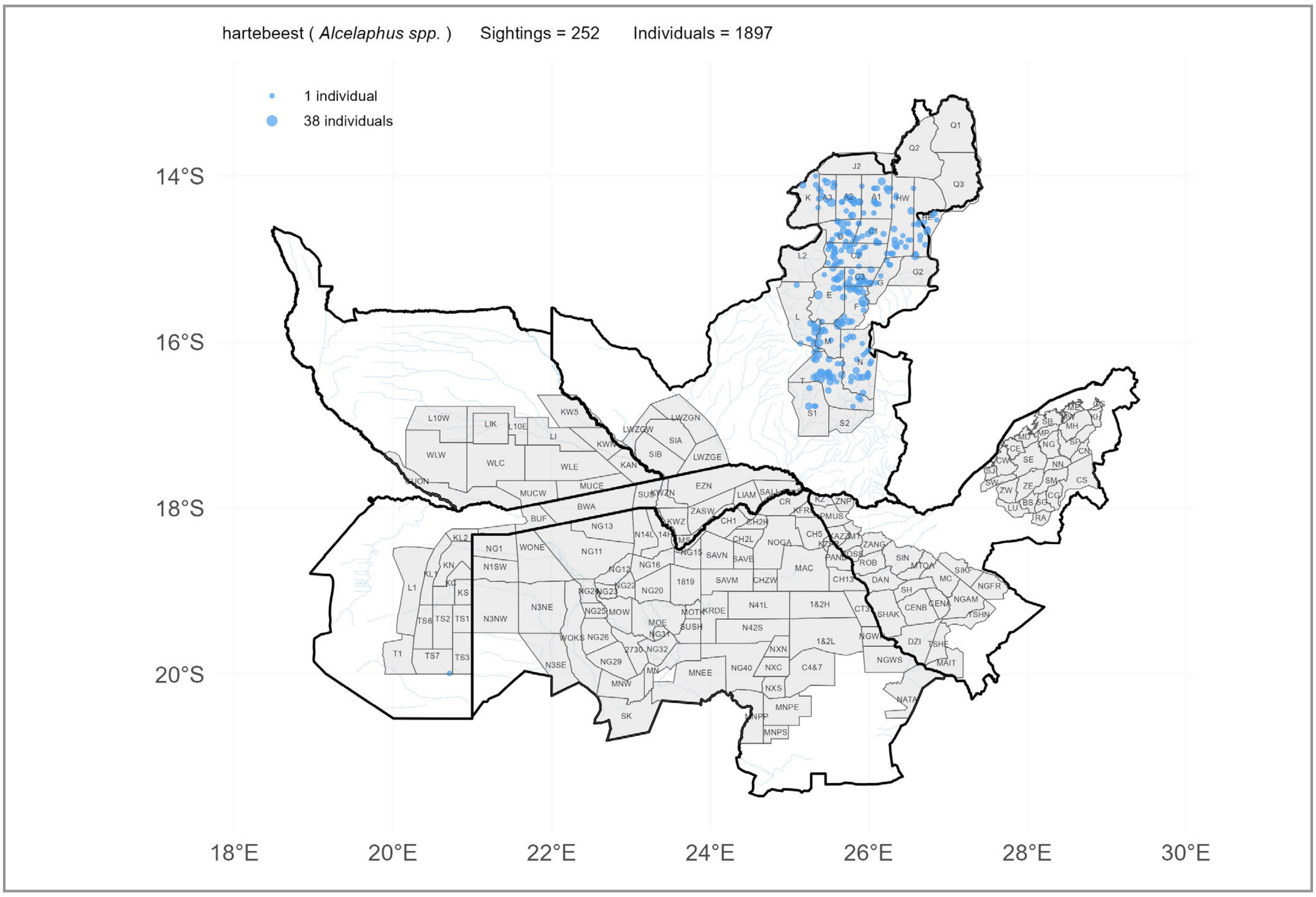


Figure 3.22: Spatial distribution of hartebeest observations in the KAZA TFCA survey area during the 2022 survey.

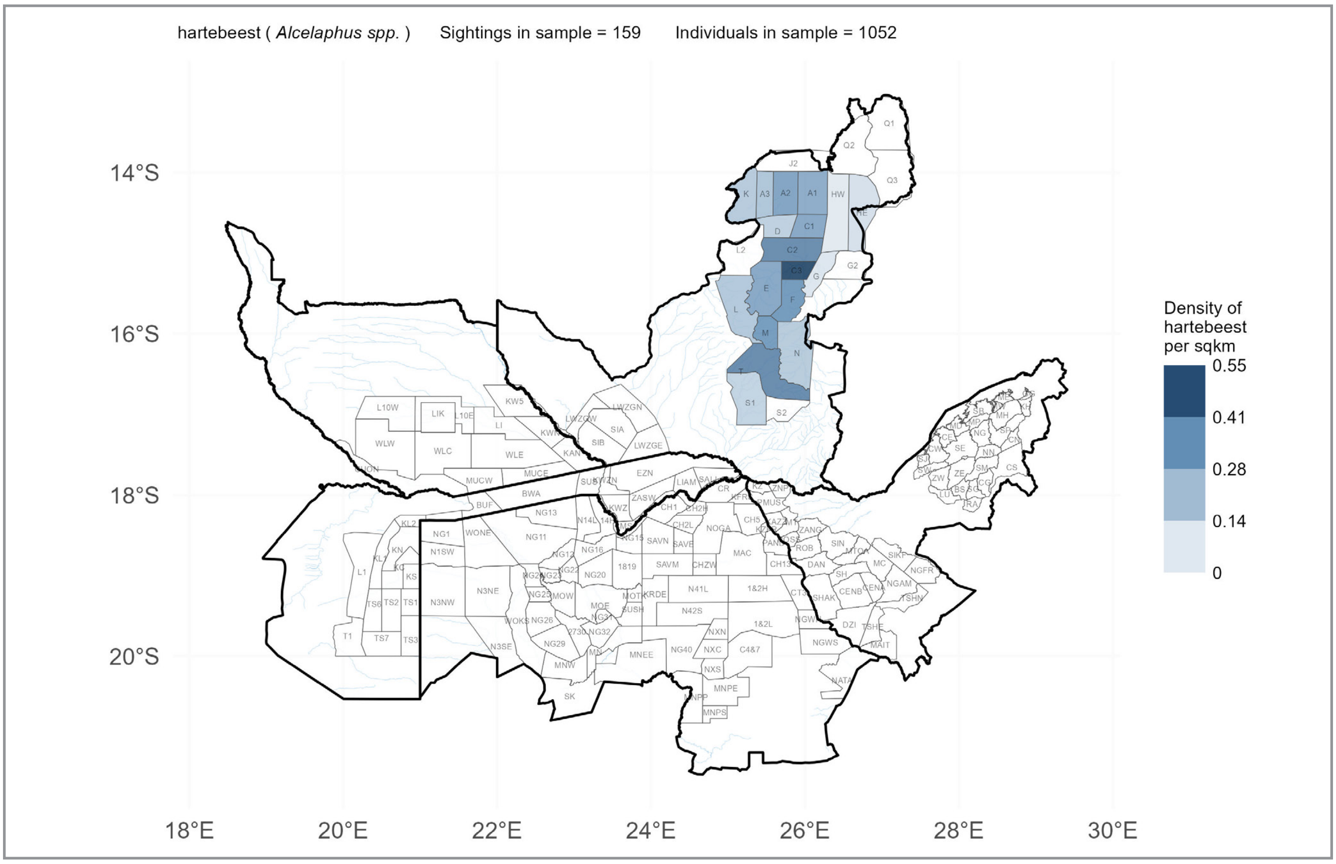


Figure 3.23: Estimated density of hartebeest in the KAZA TFCA survey area during the 2022 survey.

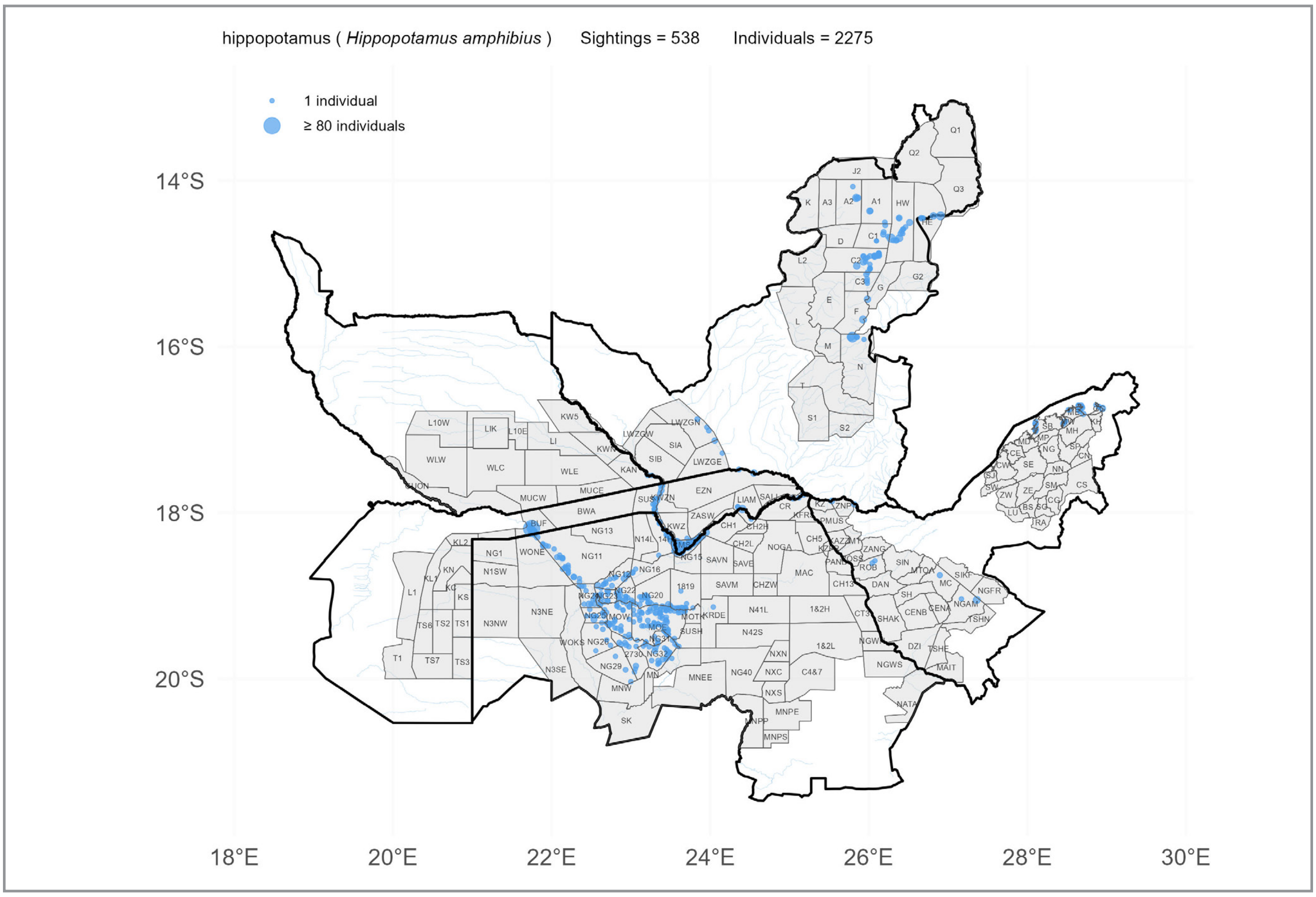


Figure 3.24: Spatial distribution of hippopotamus observations in the KAZA TFCA survey area during the 2022 survey.

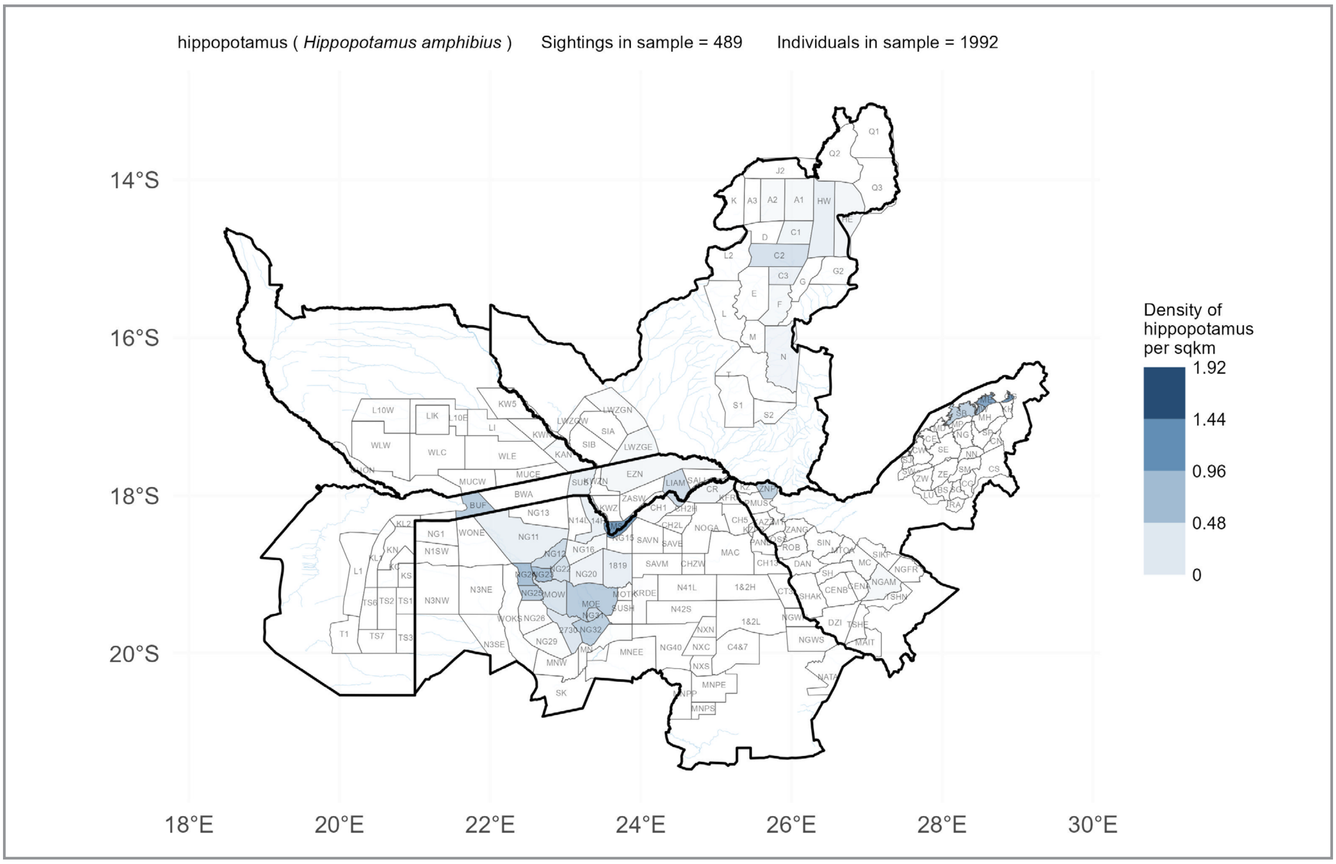


Figure 3.25: Estimated density of hippopotamus in the KAZA TFCA survey area during the 2022 survey.

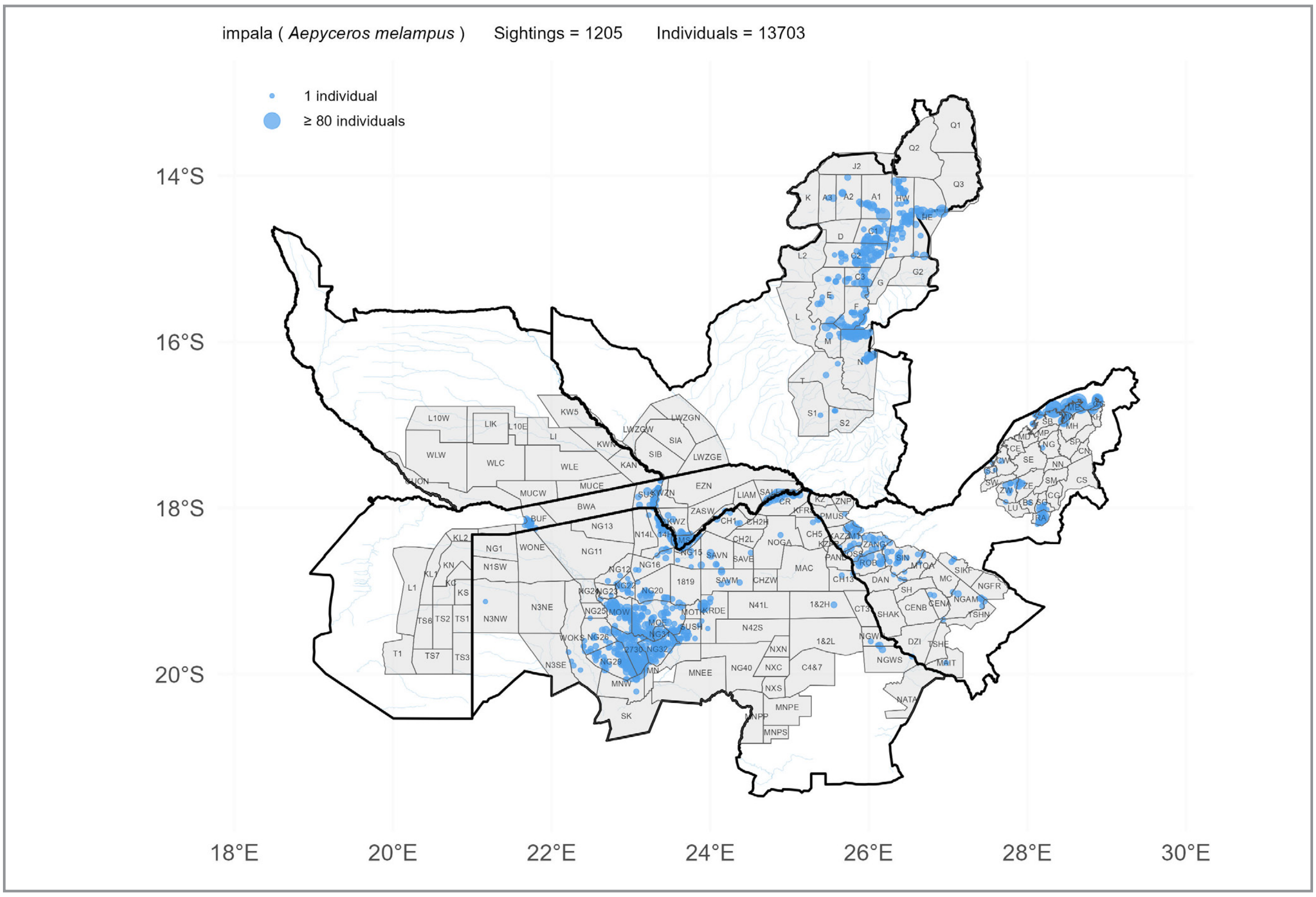


Figure 3.26: Spatial distribution of impala observations in the KAZA TFCA survey area during the 2022 survey.

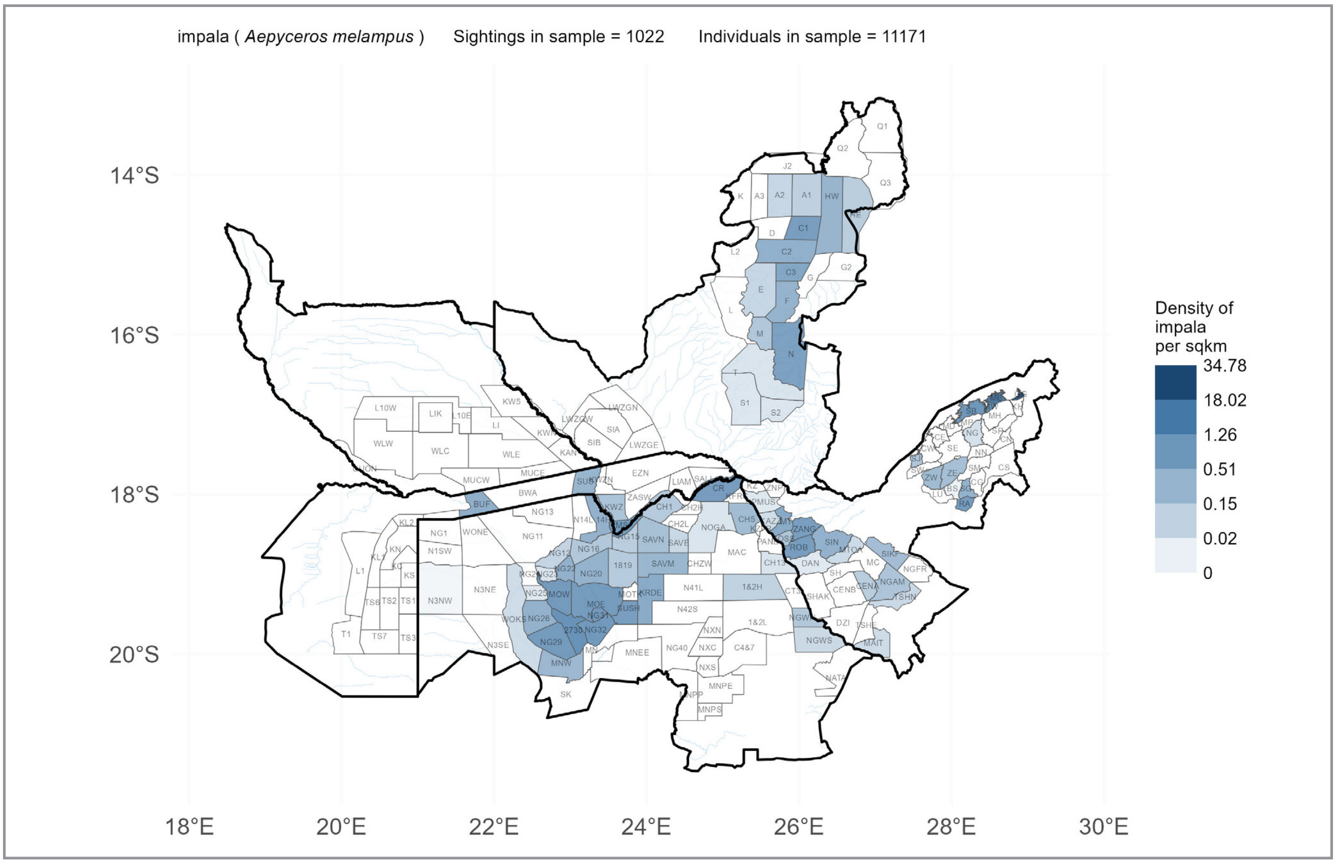


Figure 3.27: Estimated density of impala in the KAZA TFCA survey area during the 2022 survey.

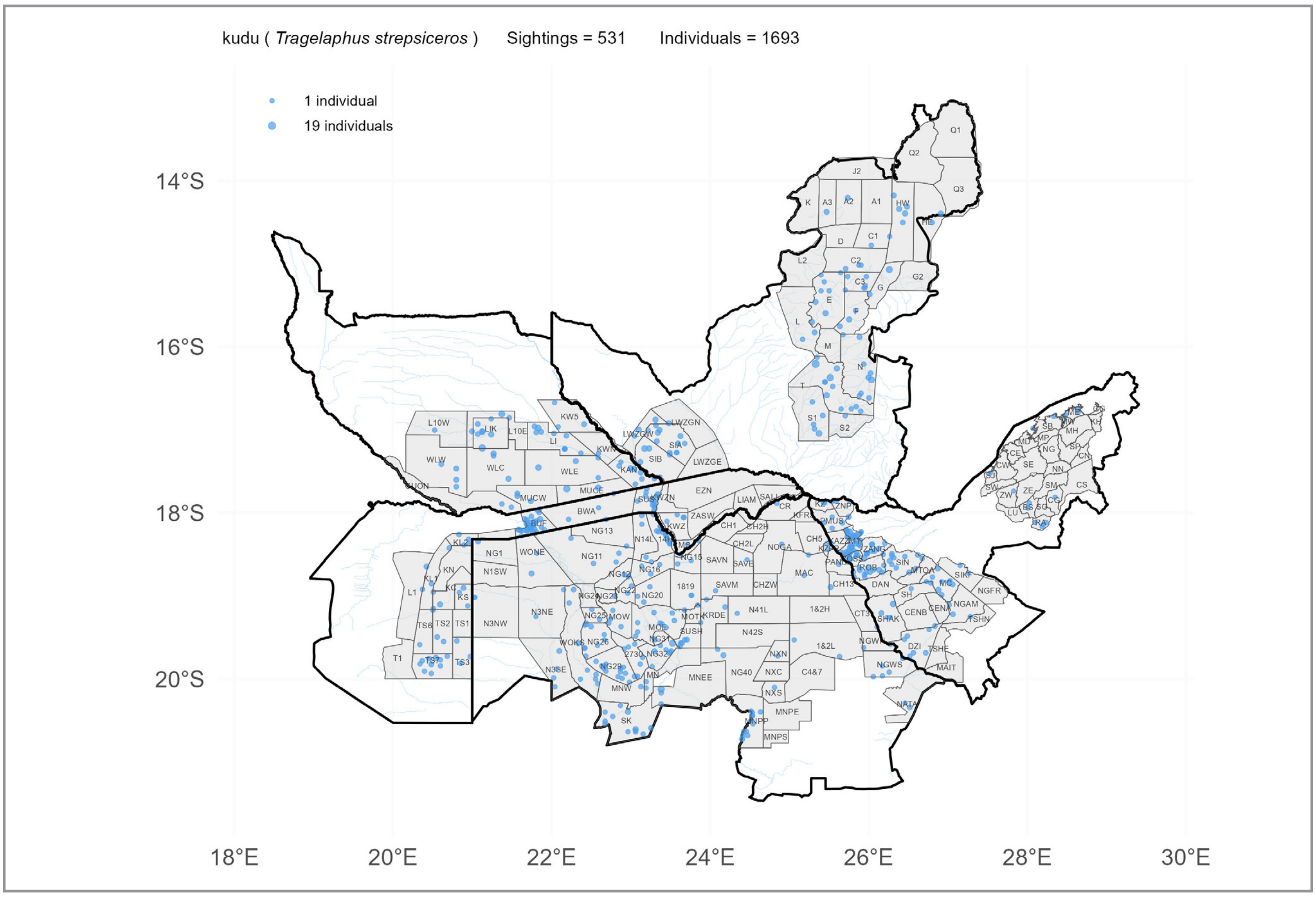


Figure 3.28: Spatial distribution of kudu observations in the KAZA TFCA survey area during the 2022 survey.

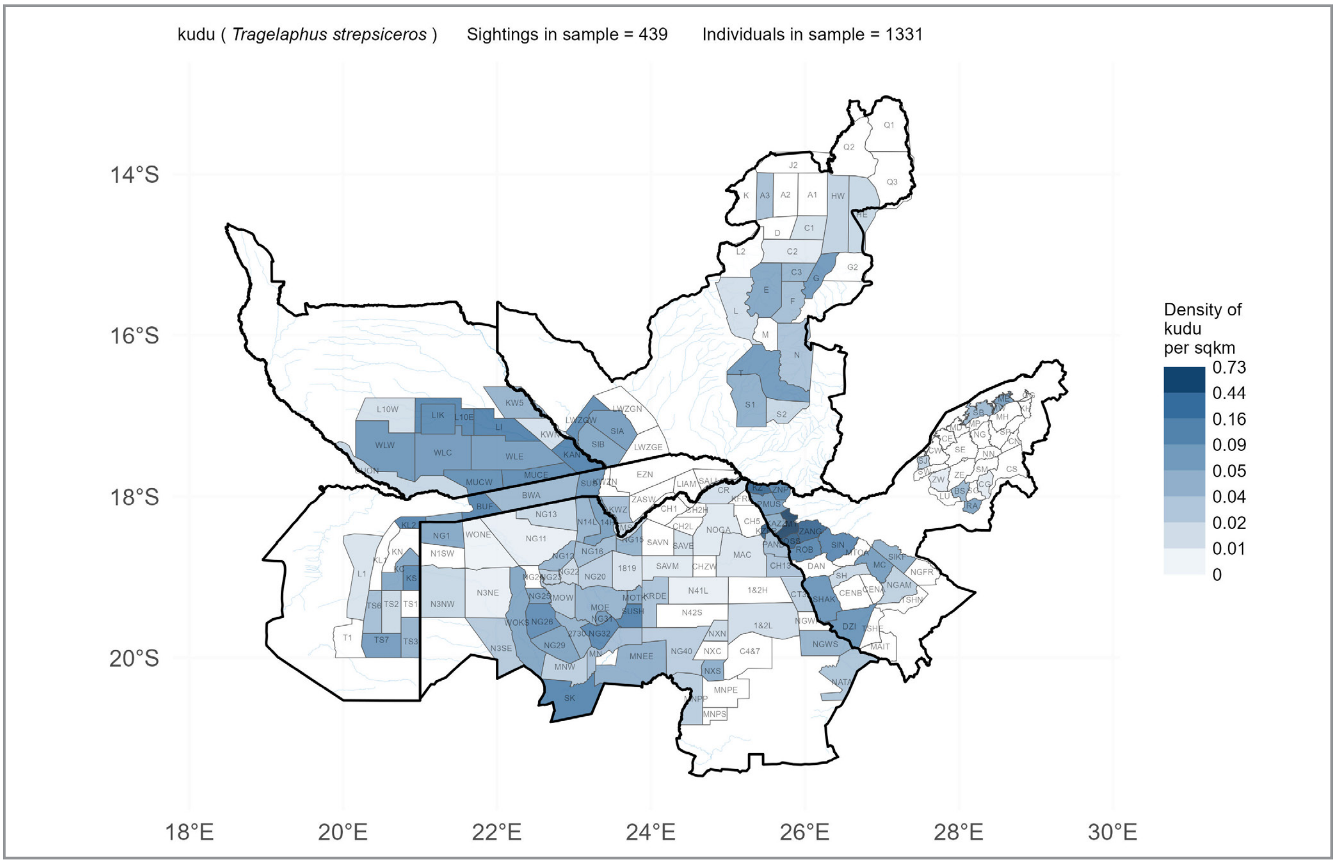


Figure 3.29: Estimated density of kudu in the KAZA TFCA survey area during the 2022 survey.

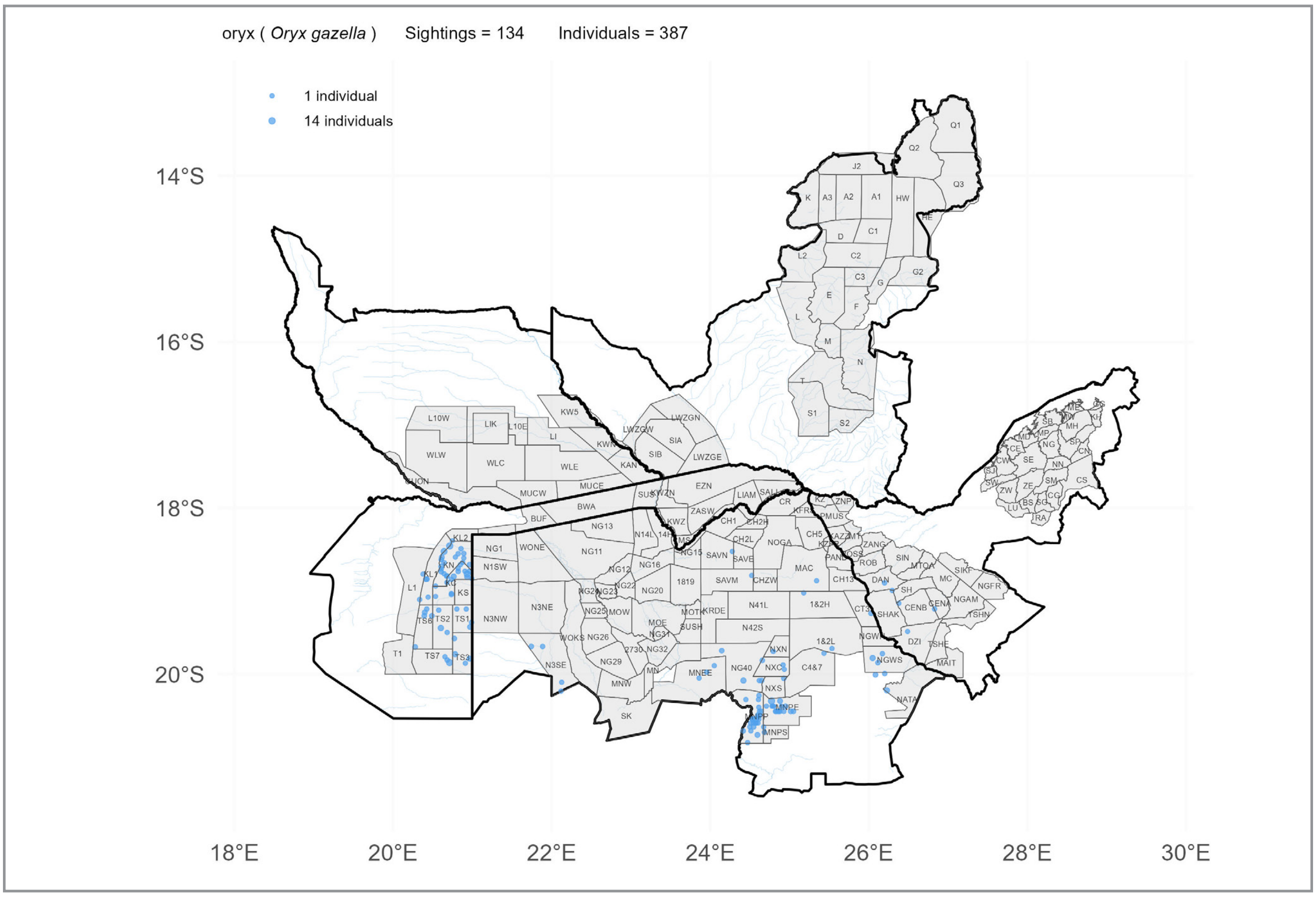


Figure 3.30: Spatial distribution of oryx observations in the KAZA TFCA survey area during the 2022 survey.

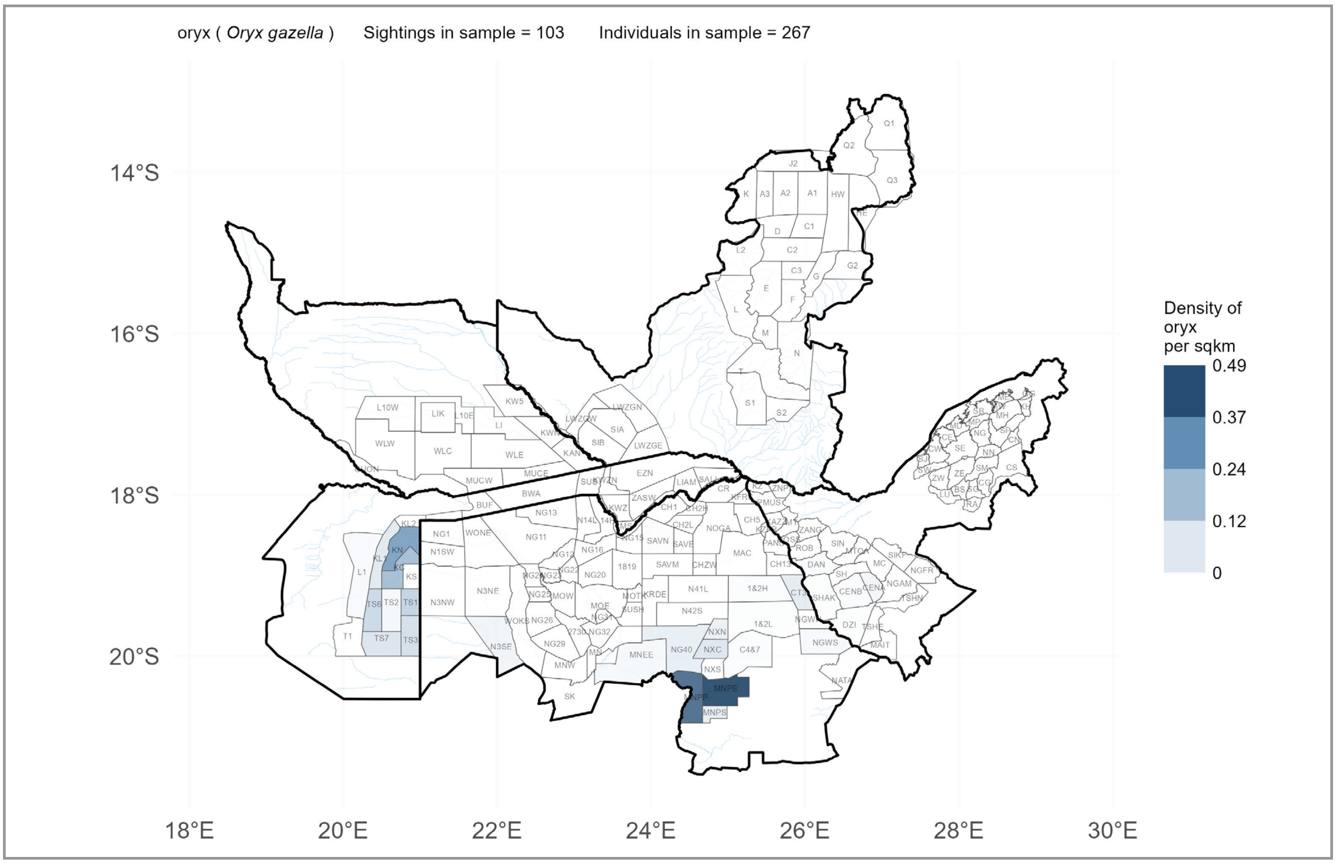


Figure 3.31: Estimated density of oryx in the KAZA TFCA survey area during the 2022 survey.

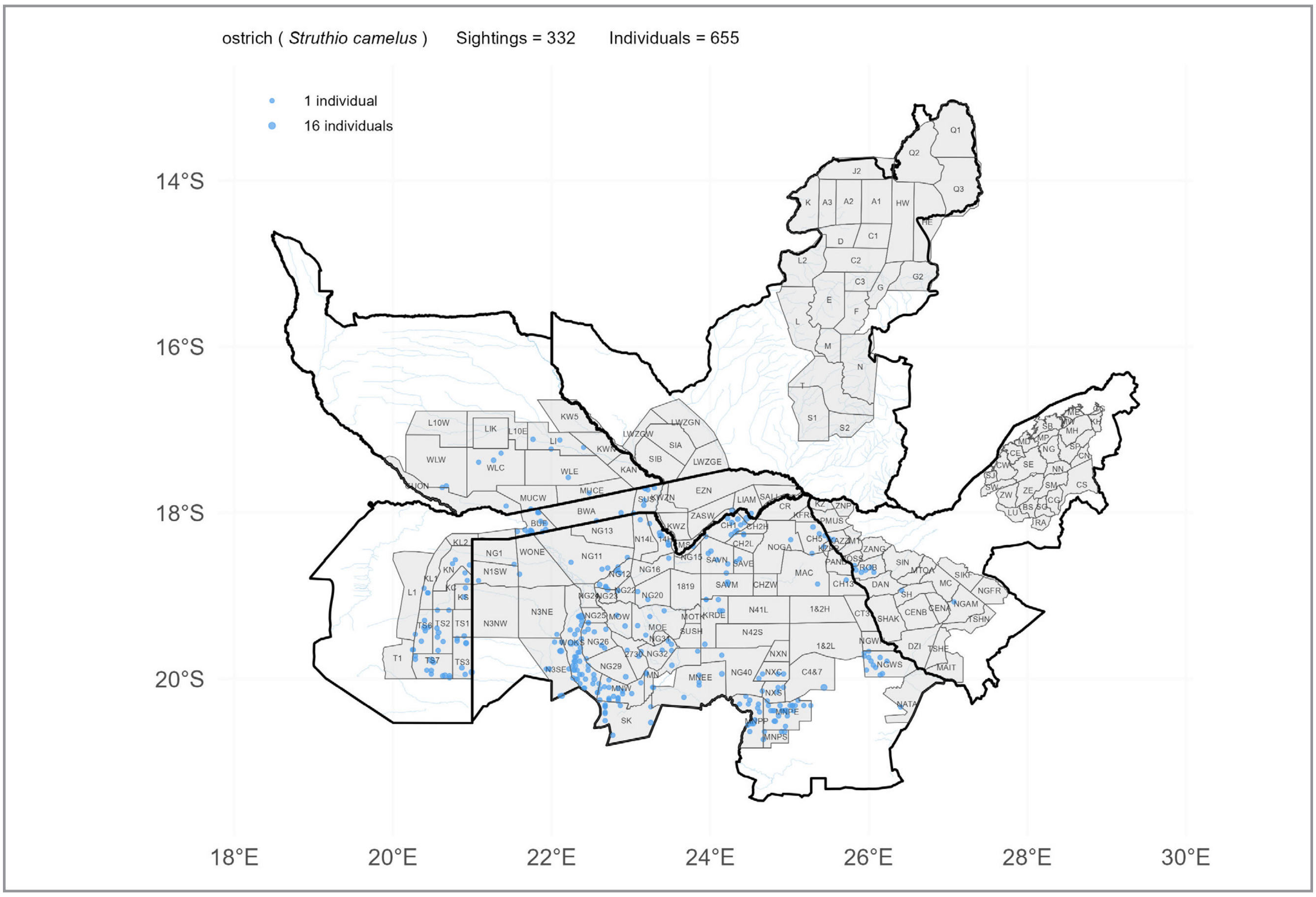


Figure 3.32: Spatial distribution of ostrich observations in the KAZA TFCA survey area during the 2022 survey.

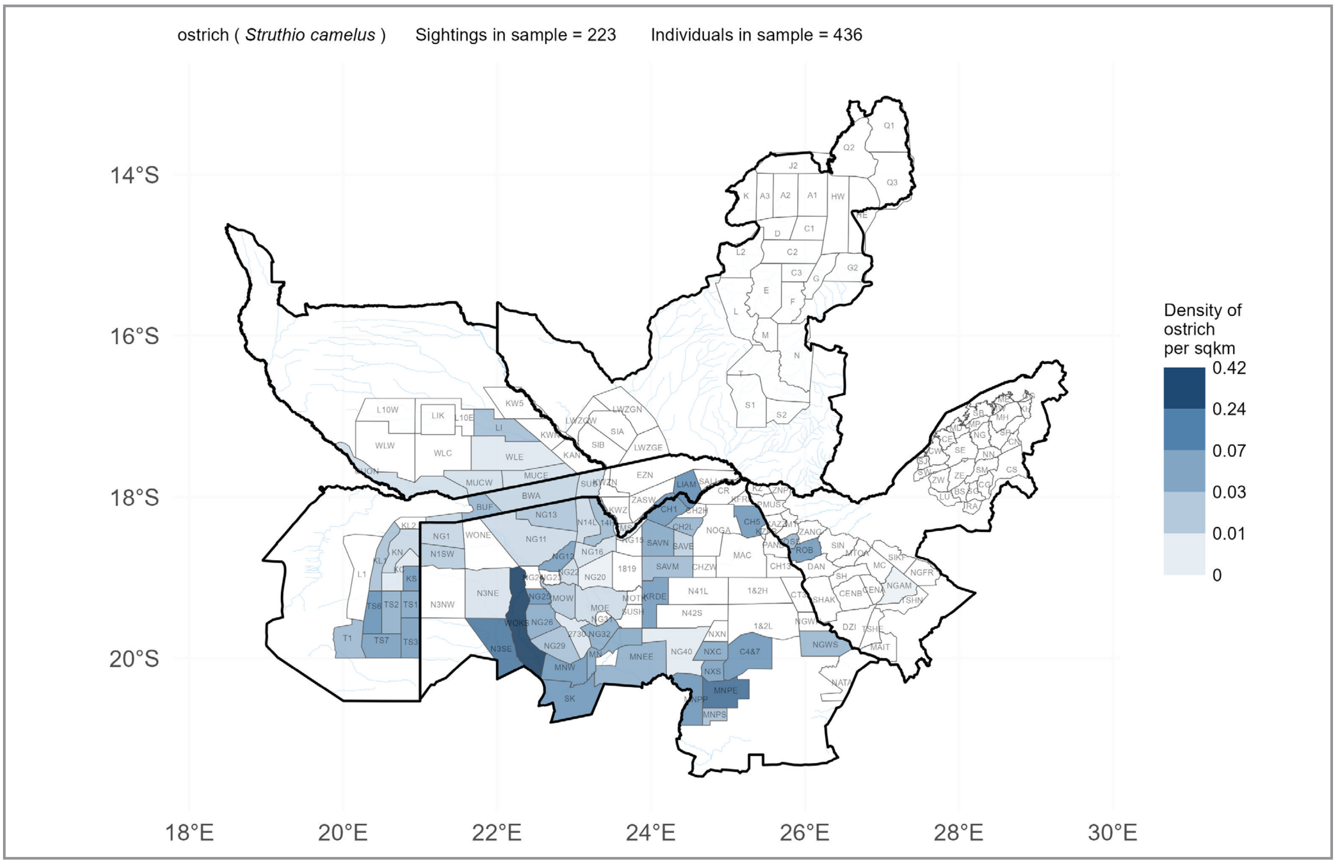


Figure 3.33: Estimated density of ostrich in the KAZA TFCA survey area during the 2022 survey.

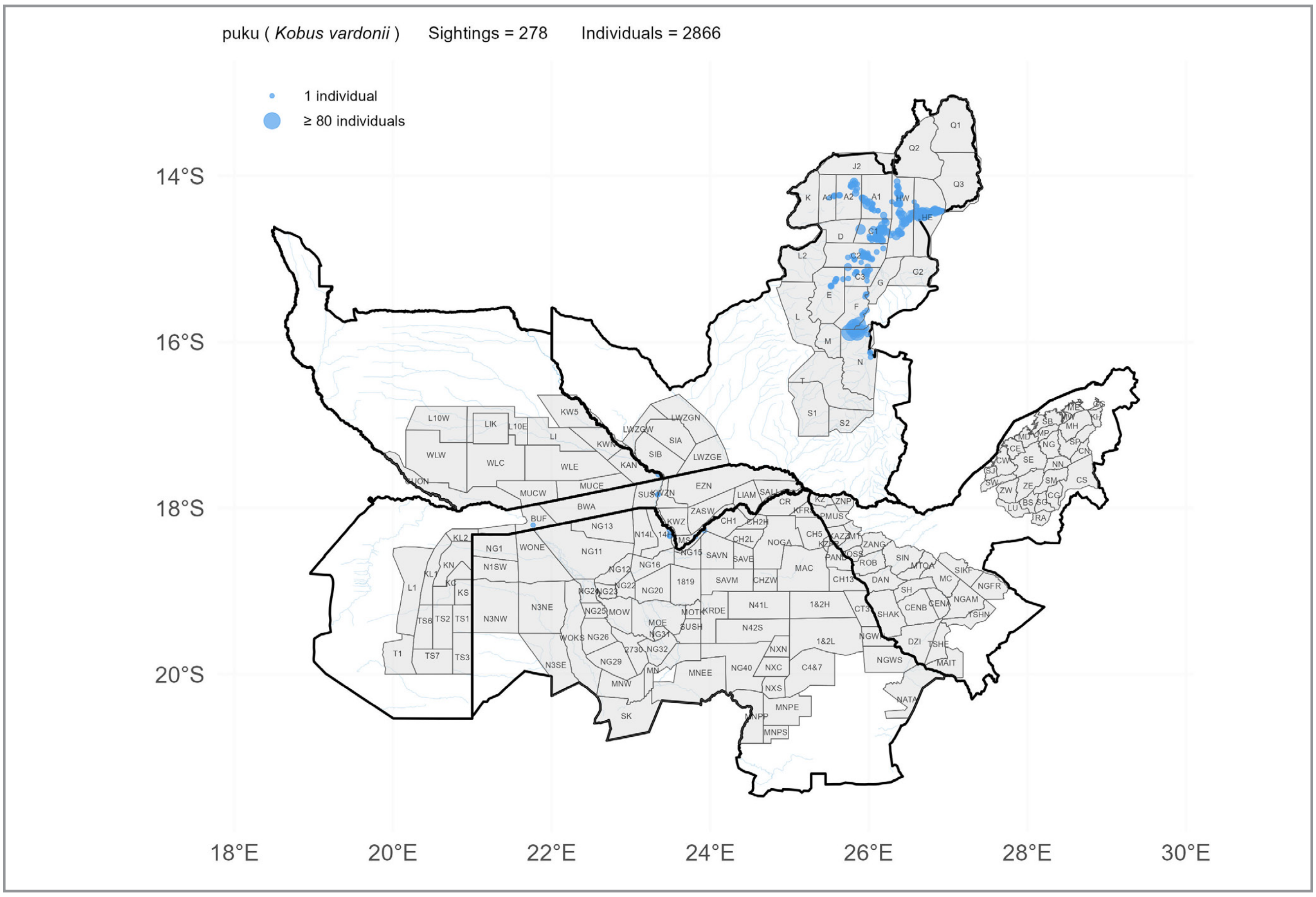


Figure 3.34: Spatial distribution of puku observations in the KAZA TFCA survey area during the 2022 survey.

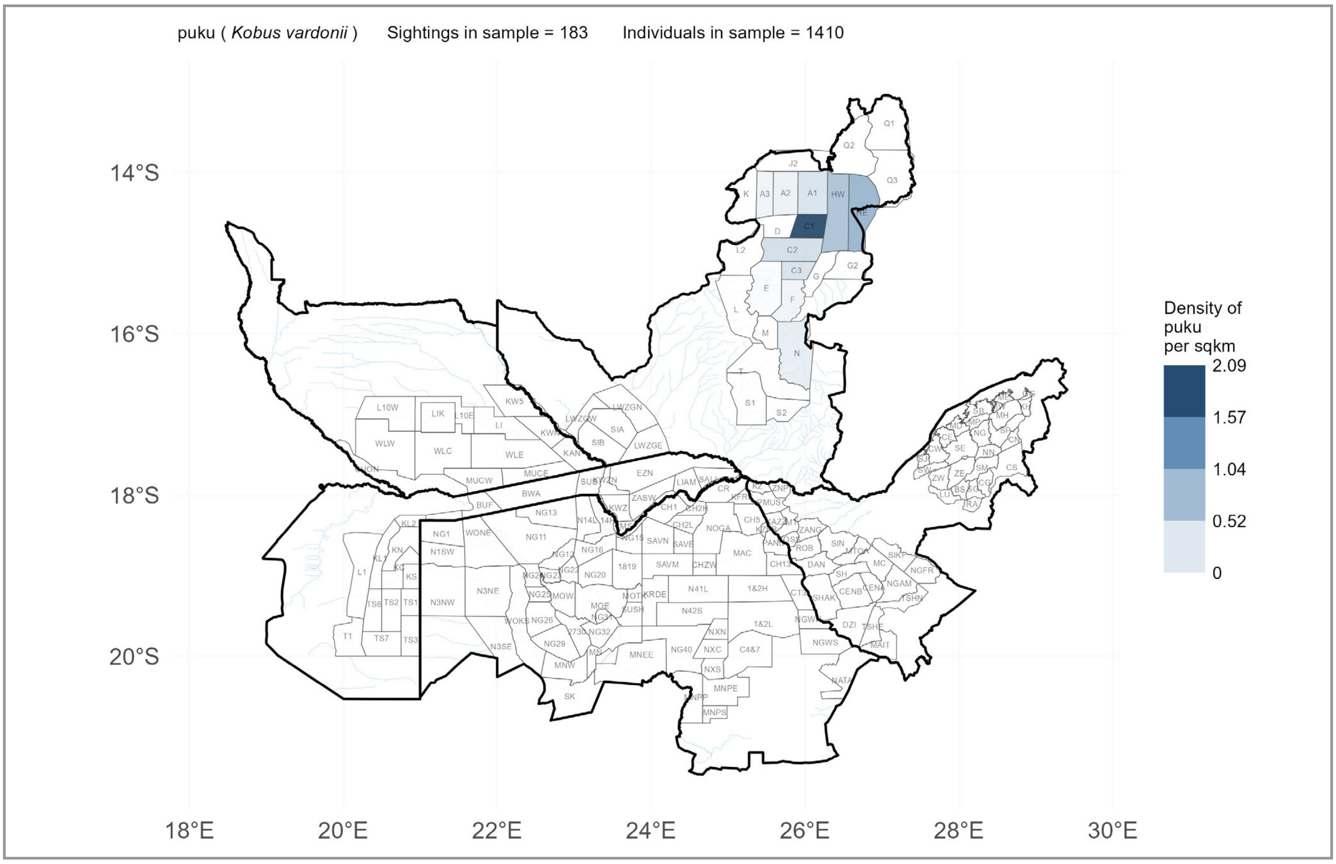


Figure 3.35: Estimated density of puku in the KAZA TFCA survey area during the 2022 survey.

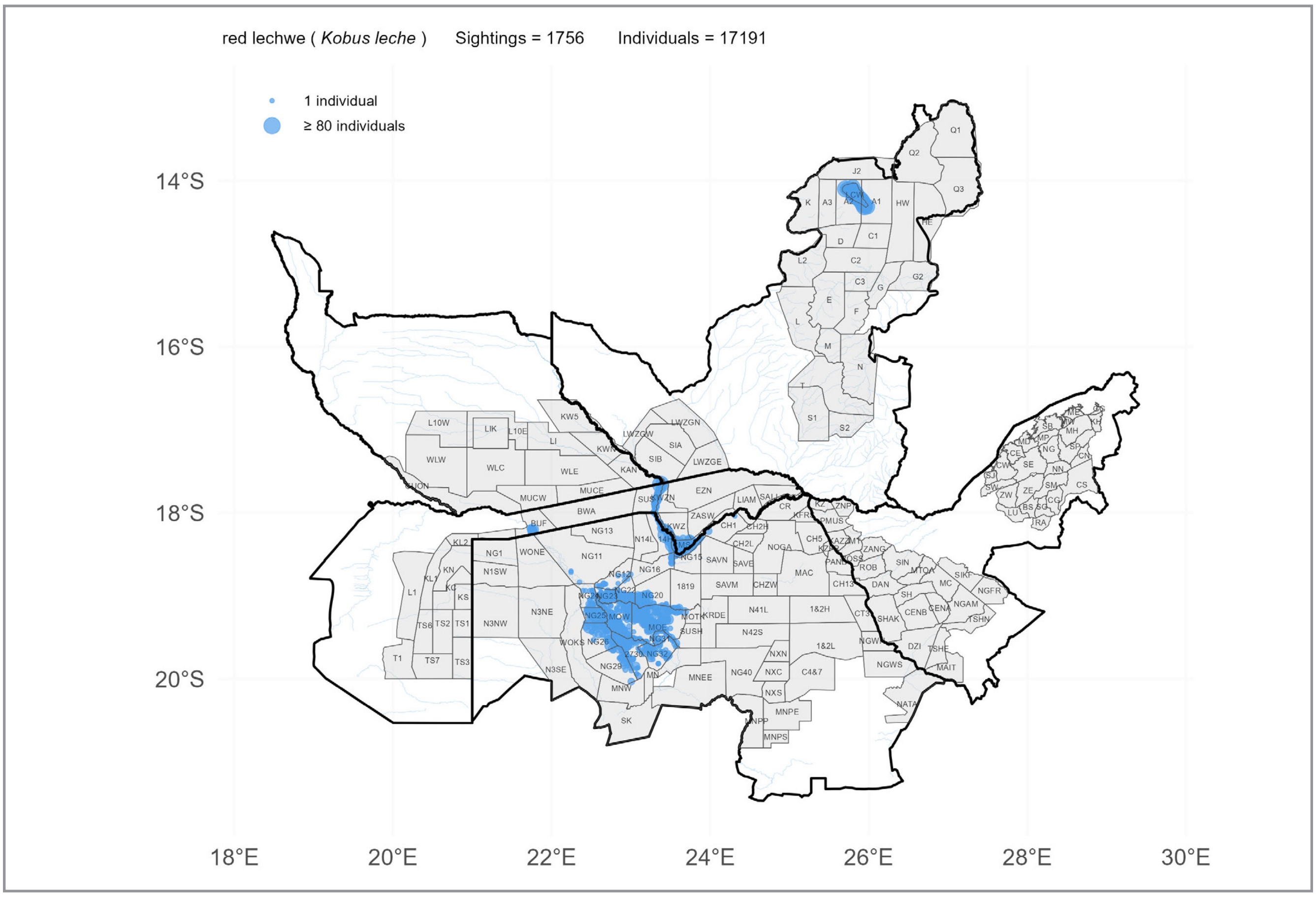


Figure 3.36: Spatial distribution of red lechwe observations in the KAZA TFCA survey area during the 2022 survey.

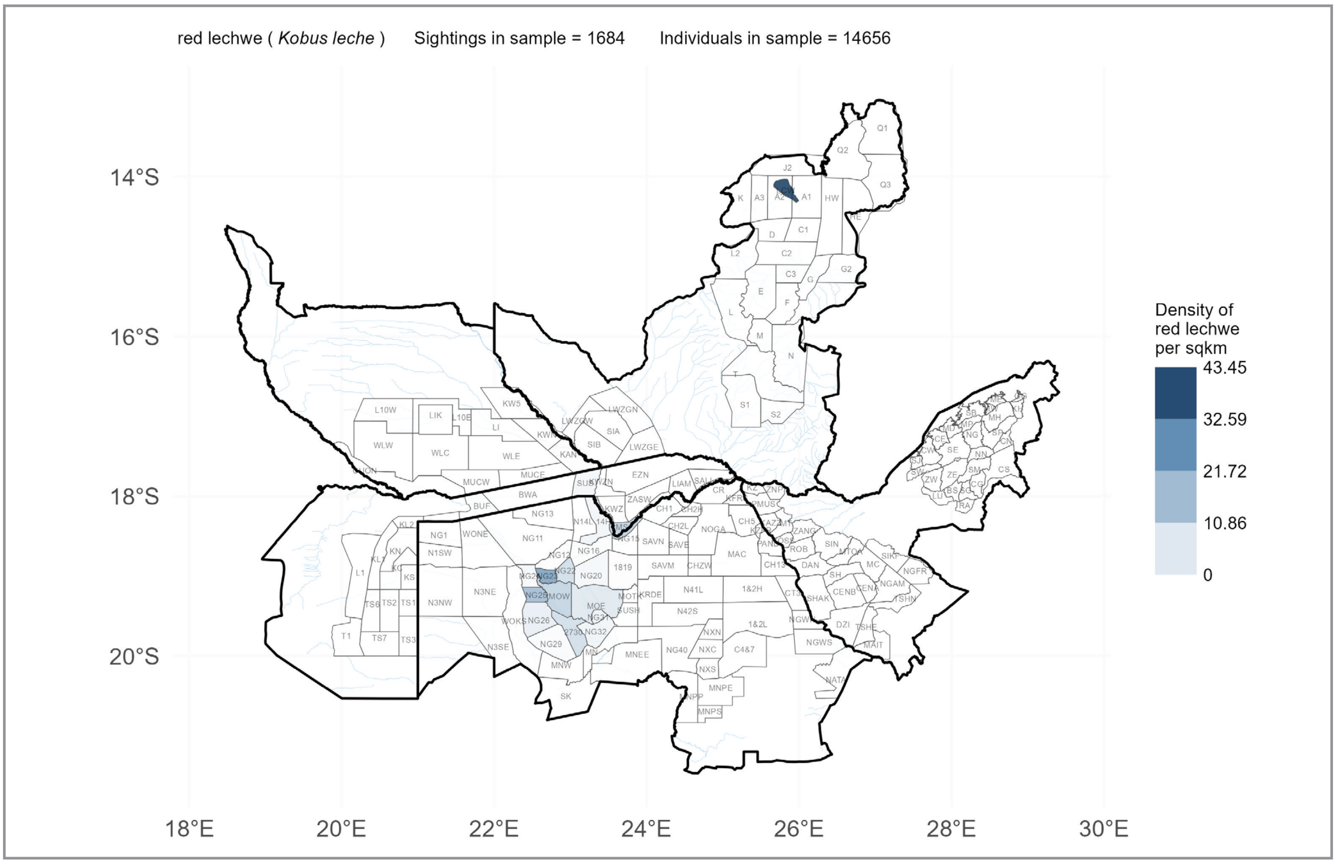


Figure 3.37: Estimated density of red lechwe in the KAZA TFCA survey area during the 2022 survey.

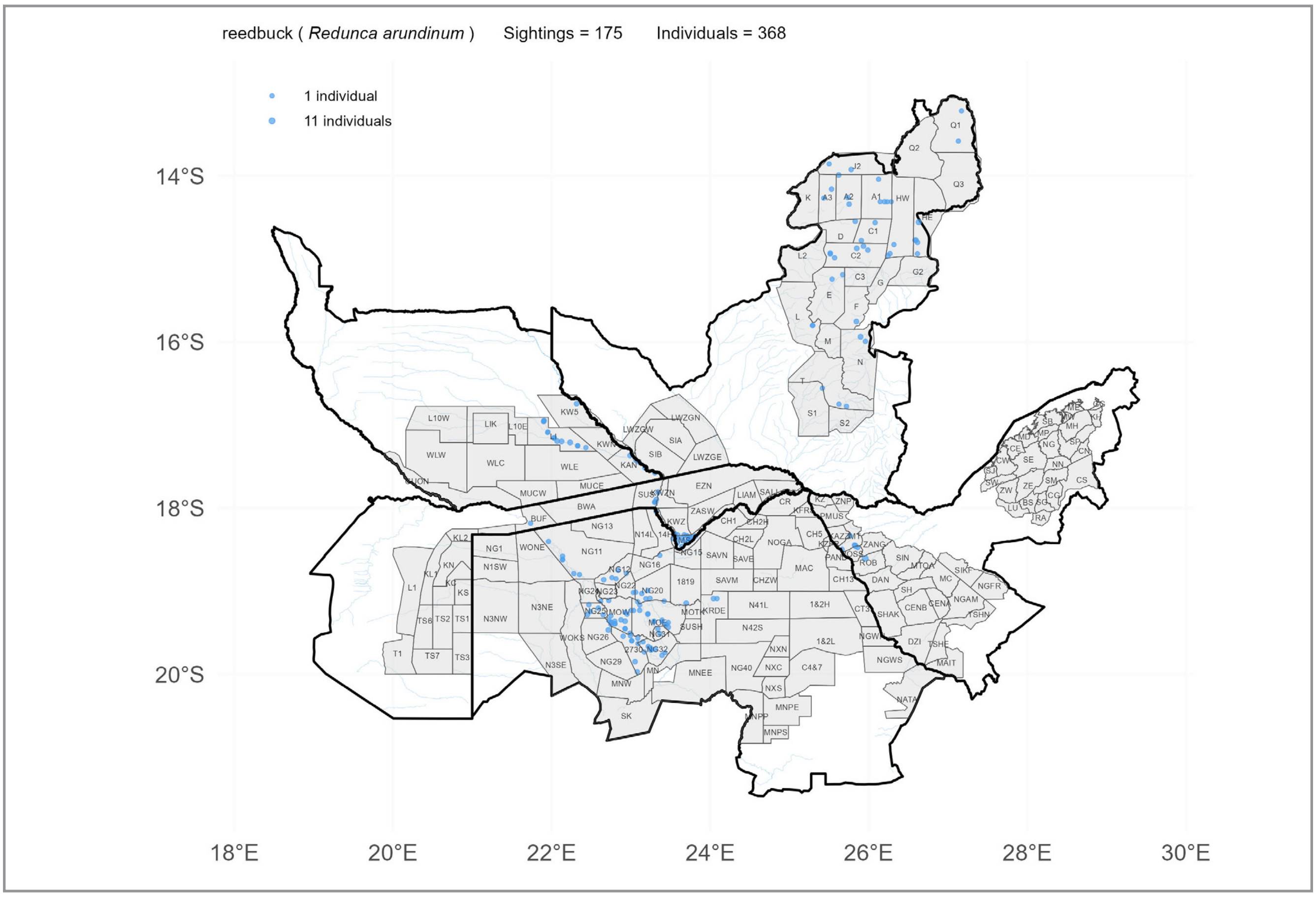


Figure 3.38: Spatial distribution of reedbuck observations in the KAZA TFCA survey area during the 2022 survey.

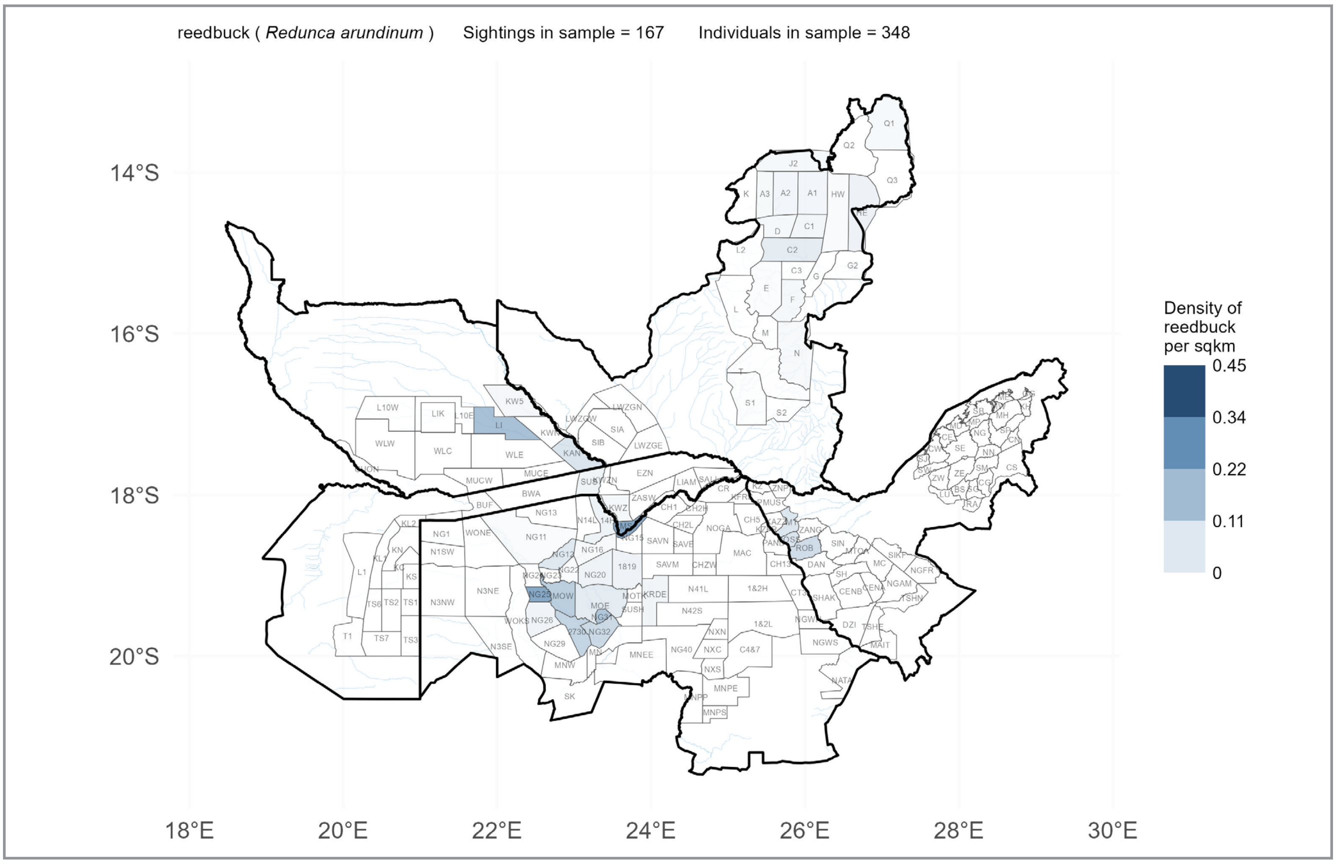


Figure 3.39: Estimated density of reedbuck in the KAZA TFCA survey area during the 2022 survey.

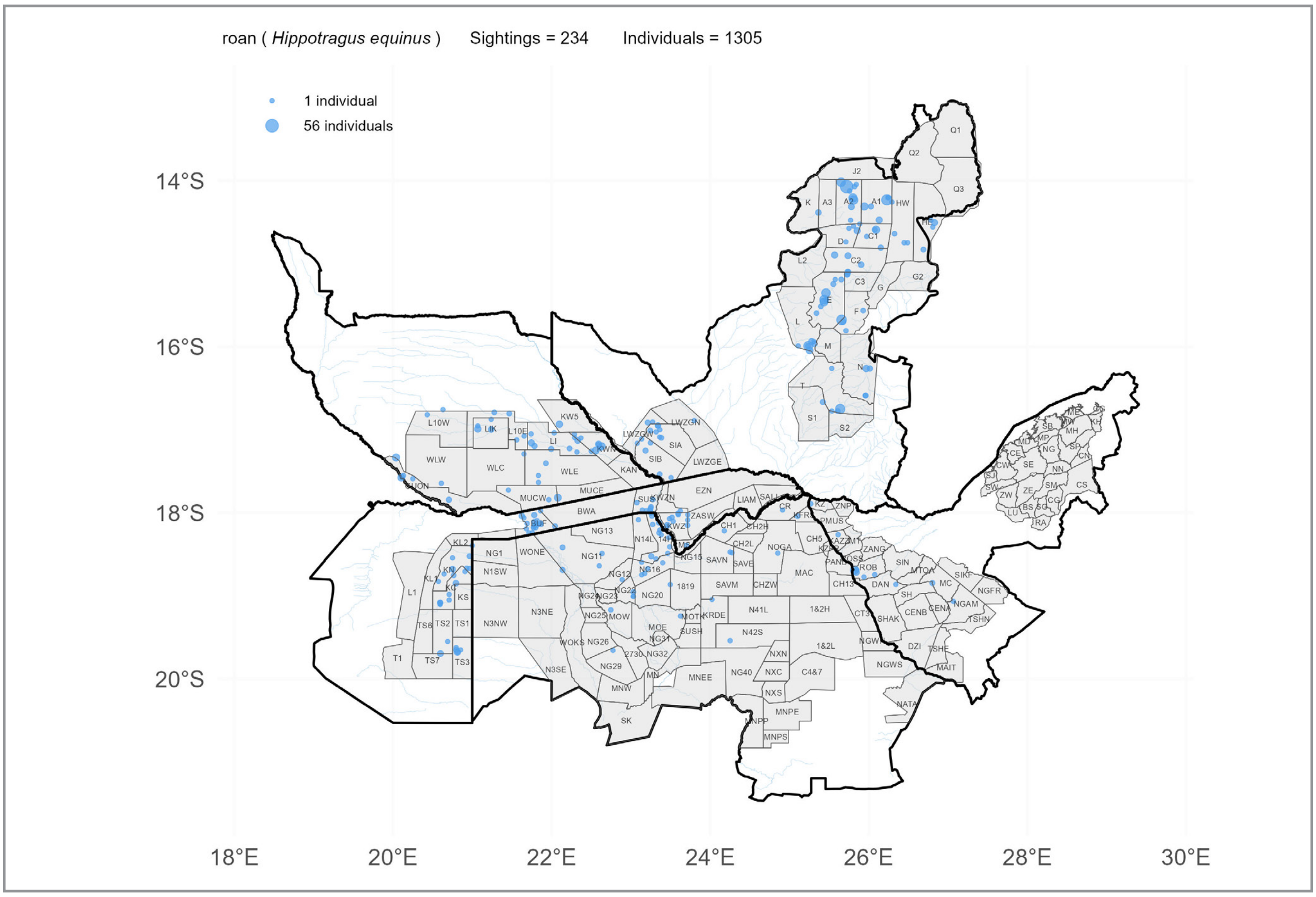


Figure 3.40: Spatial distribution of roan observations in the KAZA TFCA survey area during the 2022 survey.

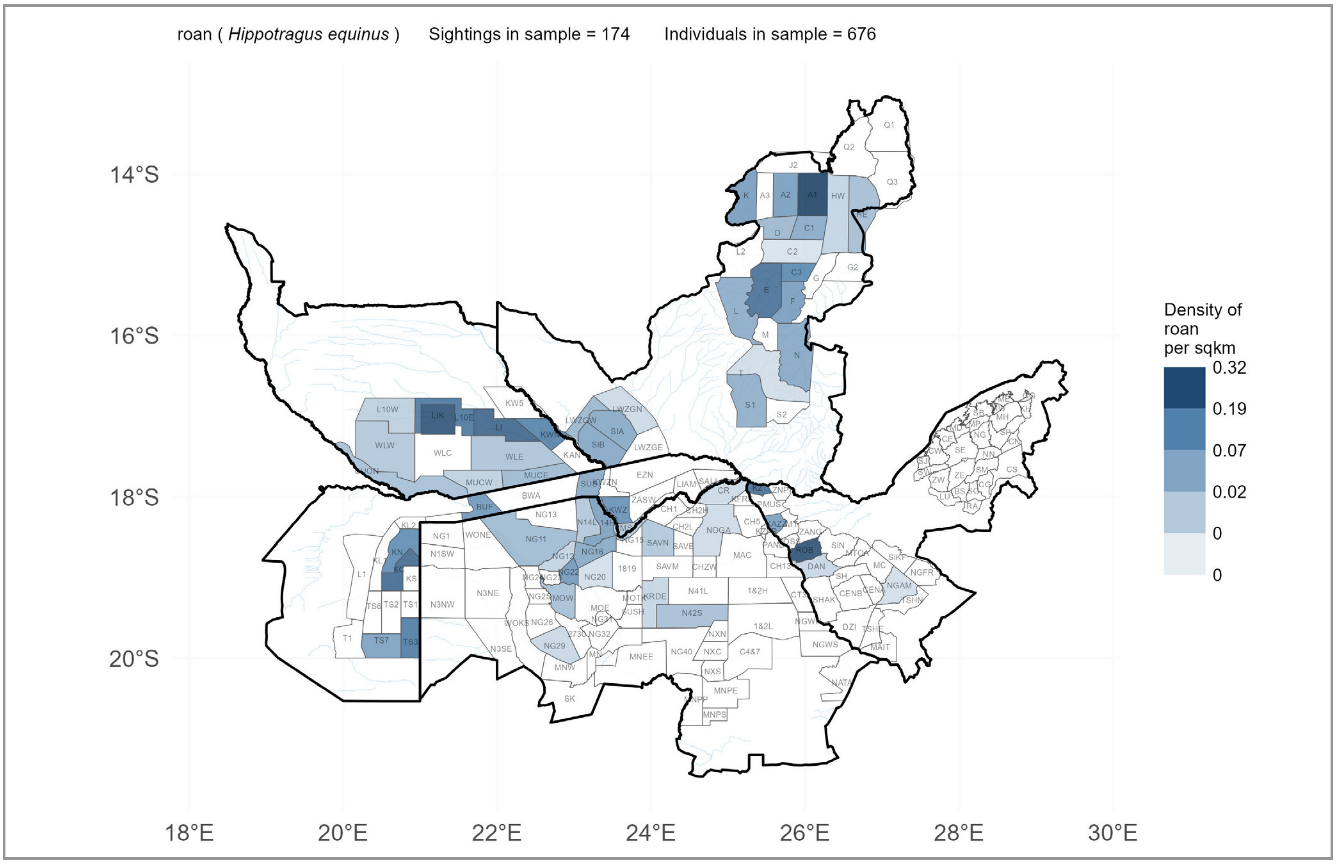


Figure 3.41: Estimated density of roan in the KAZA TFCA survey area during the 2022 survey.

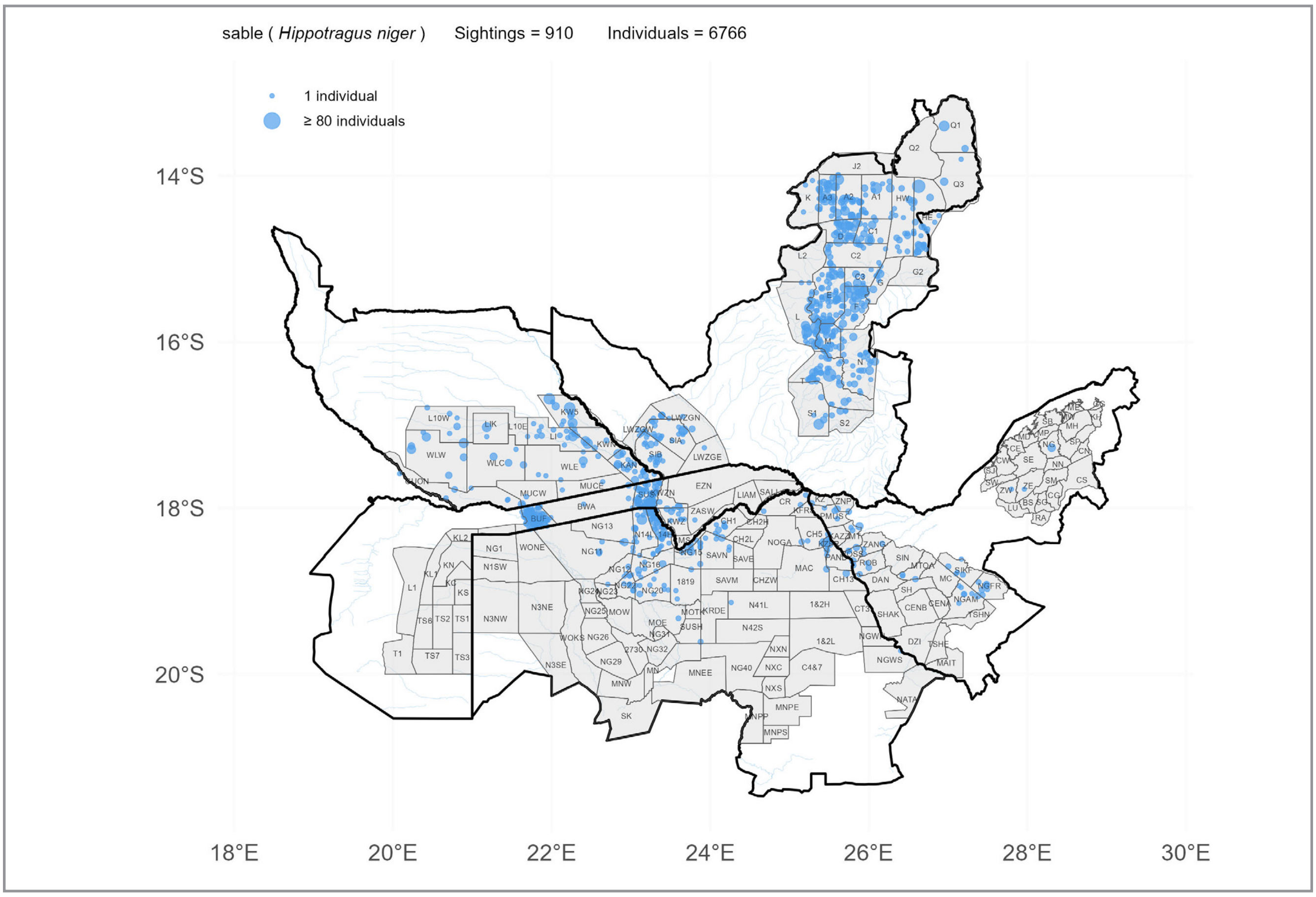


Figure 3.42: Spatial distribution of sable observations in the KAZA TFCA survey area during the 2022 survey.

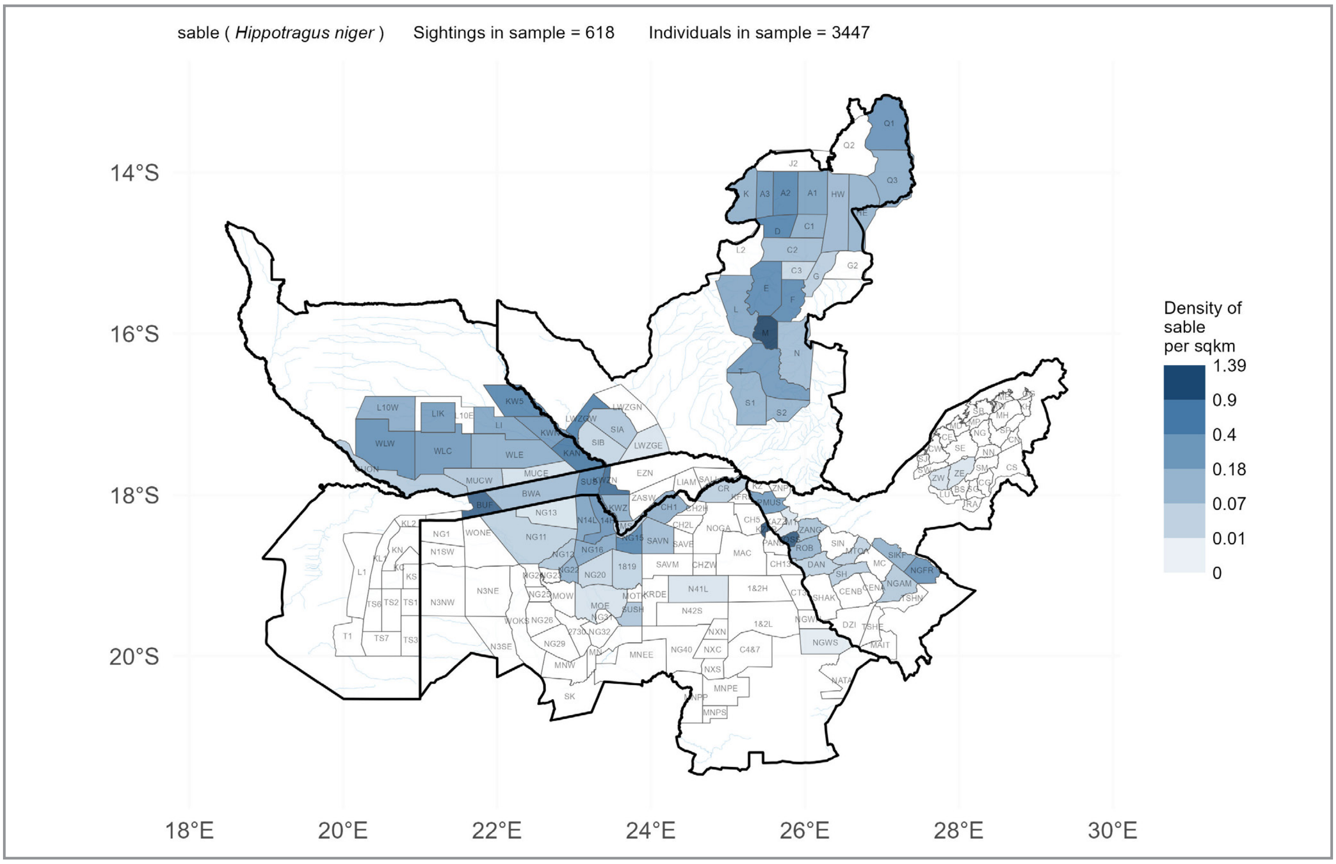


Figure 3.43: Estimated density of sable in the KAZA TFCA survey area during the 2022 survey.

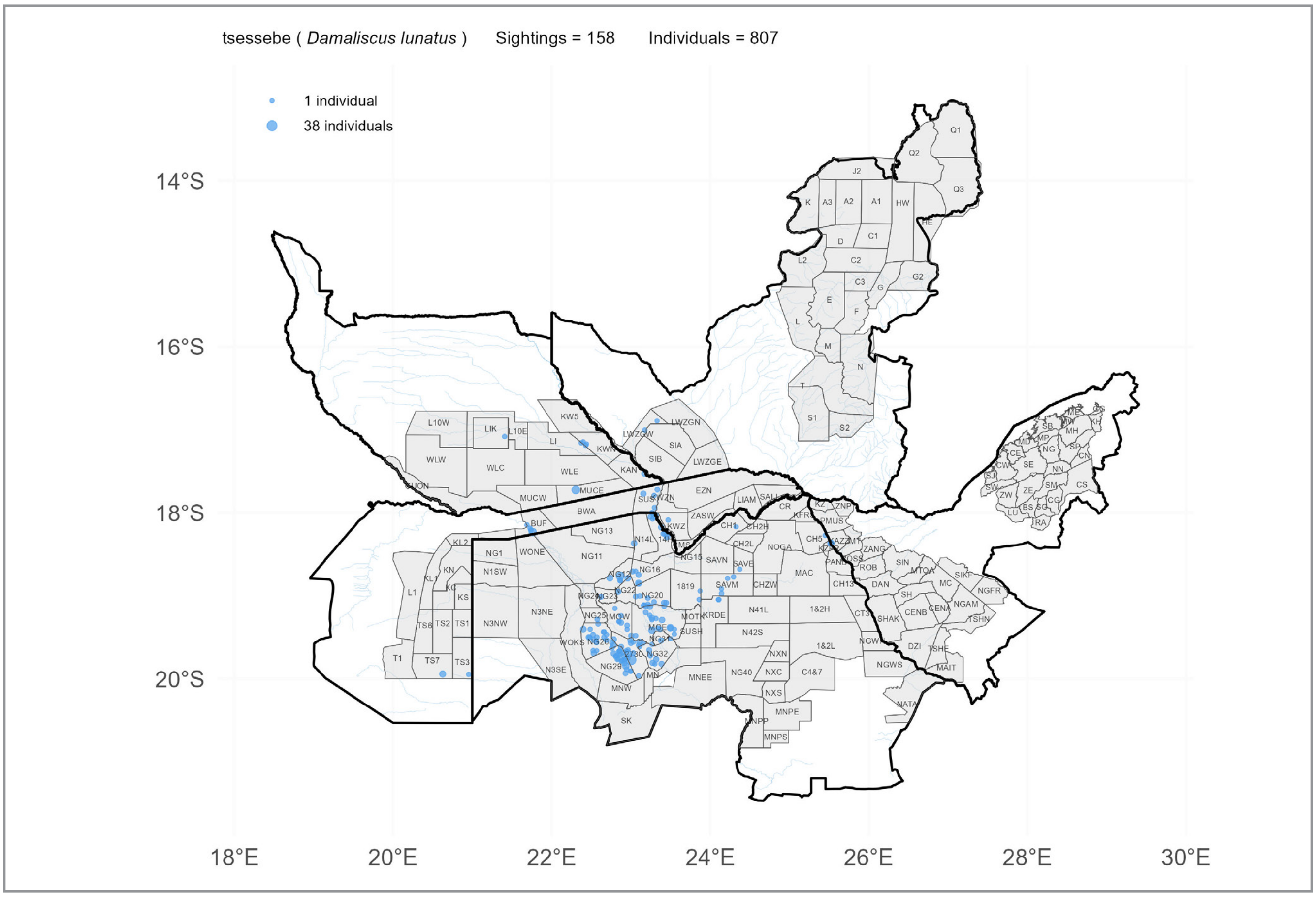


Figure 3.44: Spatial distribution of tsessebe observations in the KAZA TFCA survey area during the 2022 survey.

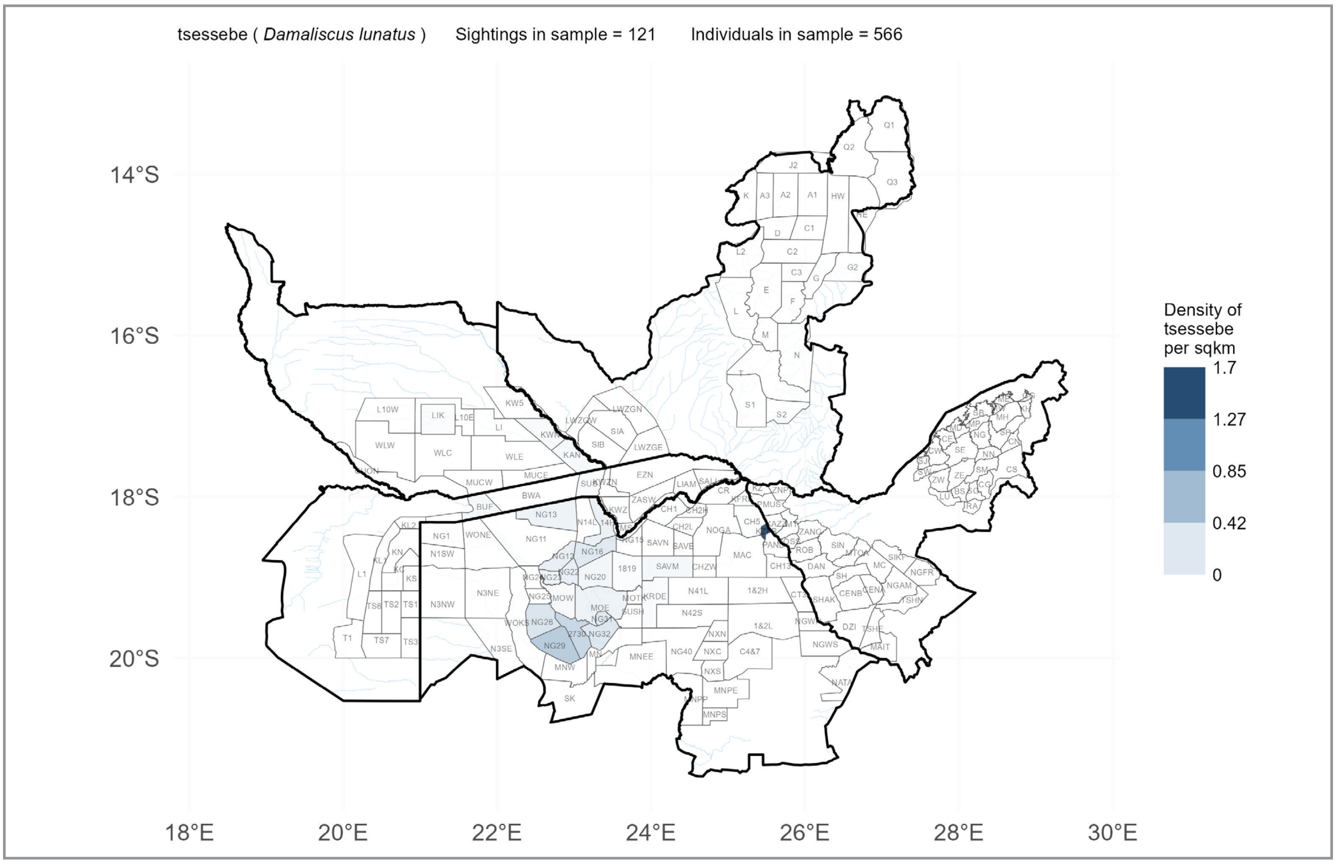


Figure 3.45: Estimated density of tsessebe in the KAZA TFCA survey area during the 2022 survey.

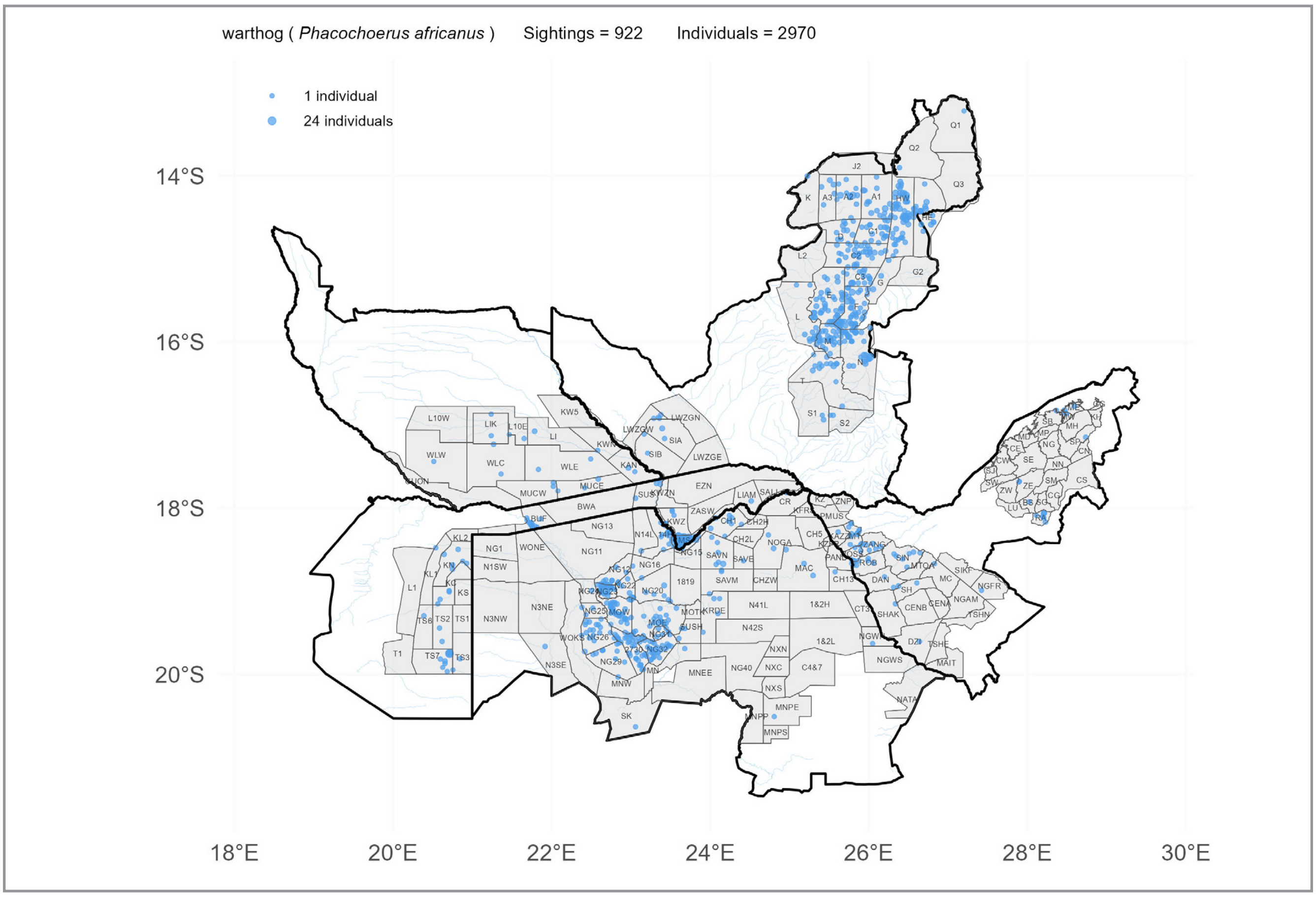


Figure 3.46: Spatial distribution of warthog observations in the KAZA TFCA survey area during the 2022 survey.

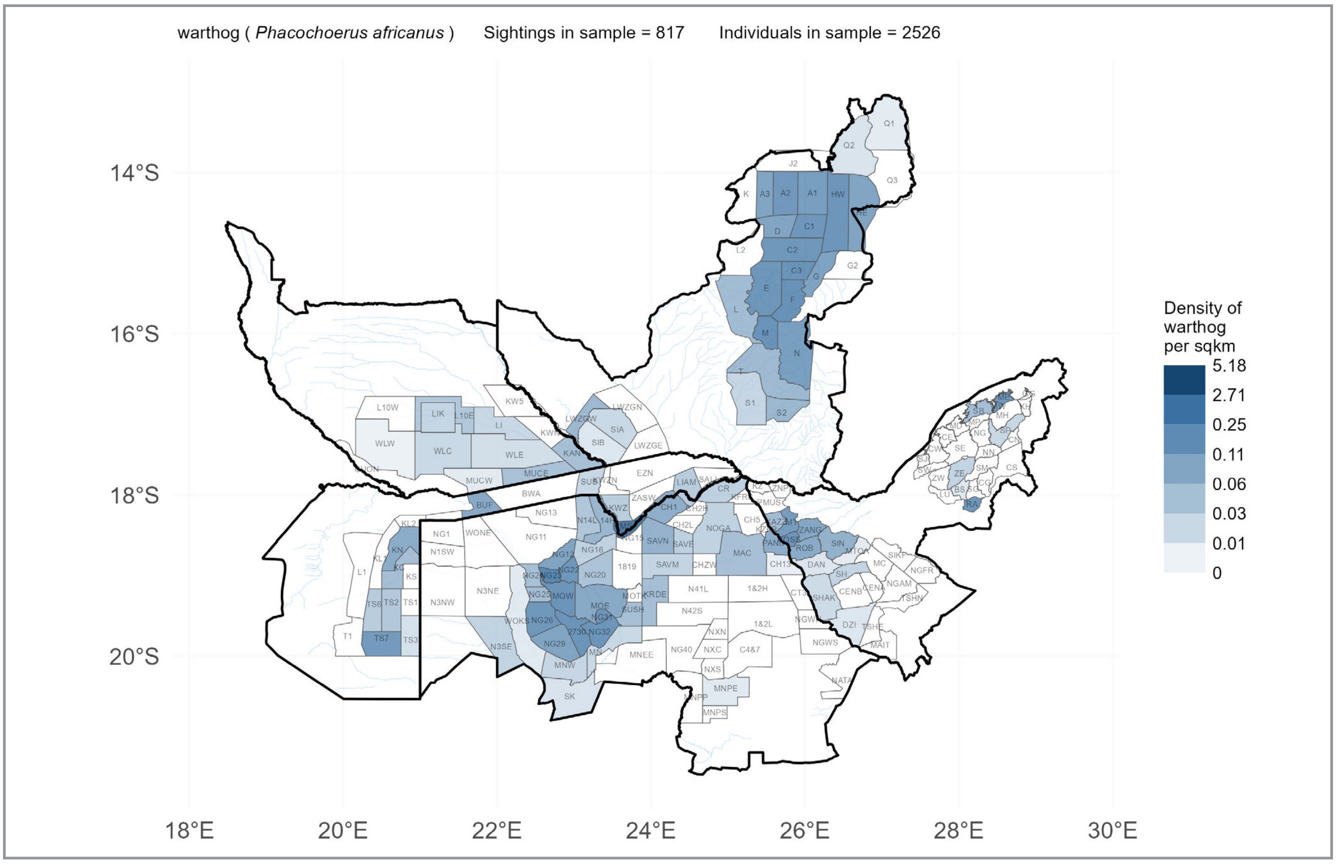


Figure 3.47: Estimated density of warthog in the KAZA TFCA survey area during the 2022 survey.

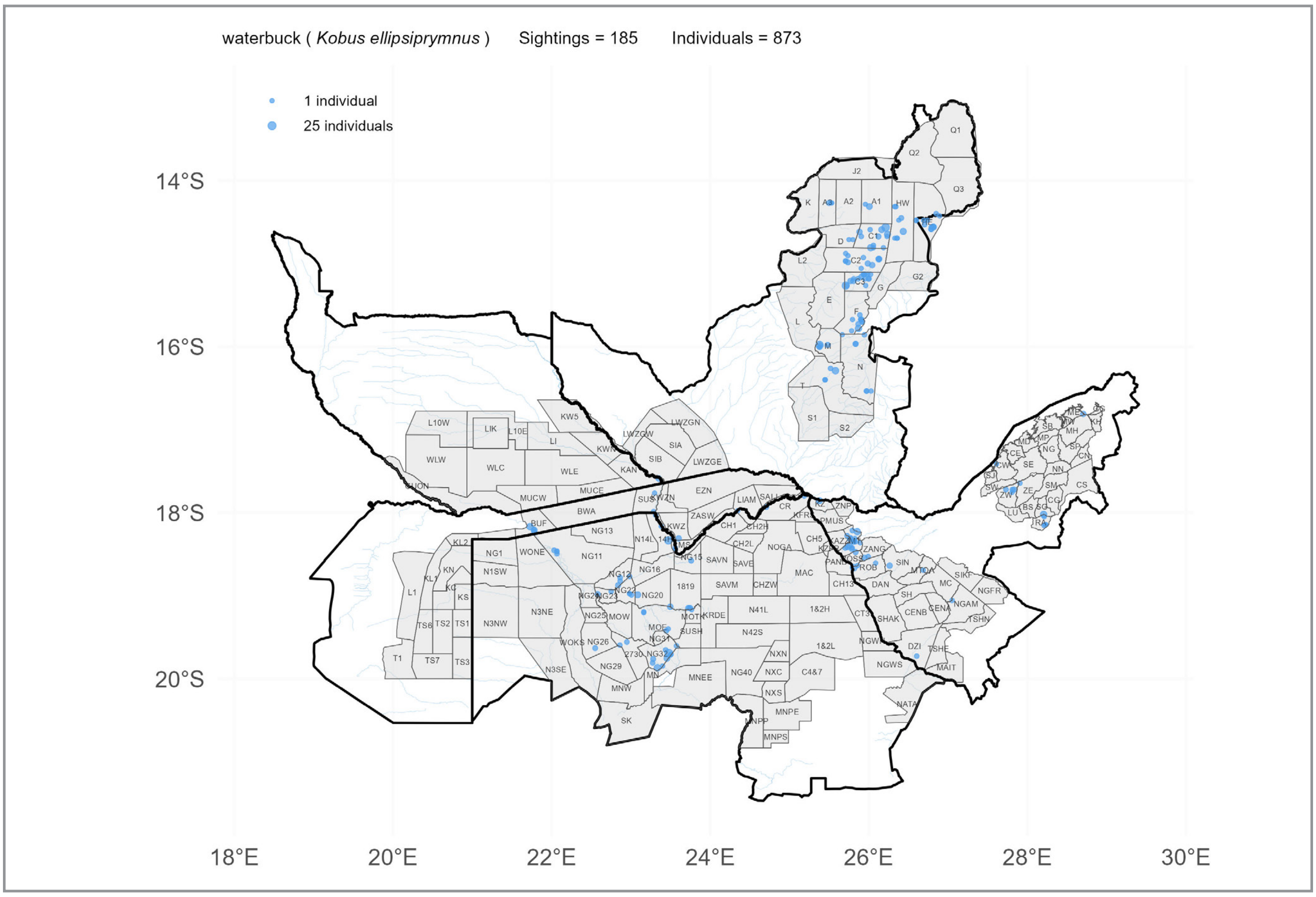


Figure 3.48: Spatial distribution of waterbuck observations in the KAZA TFCA survey area during the 2022 survey.

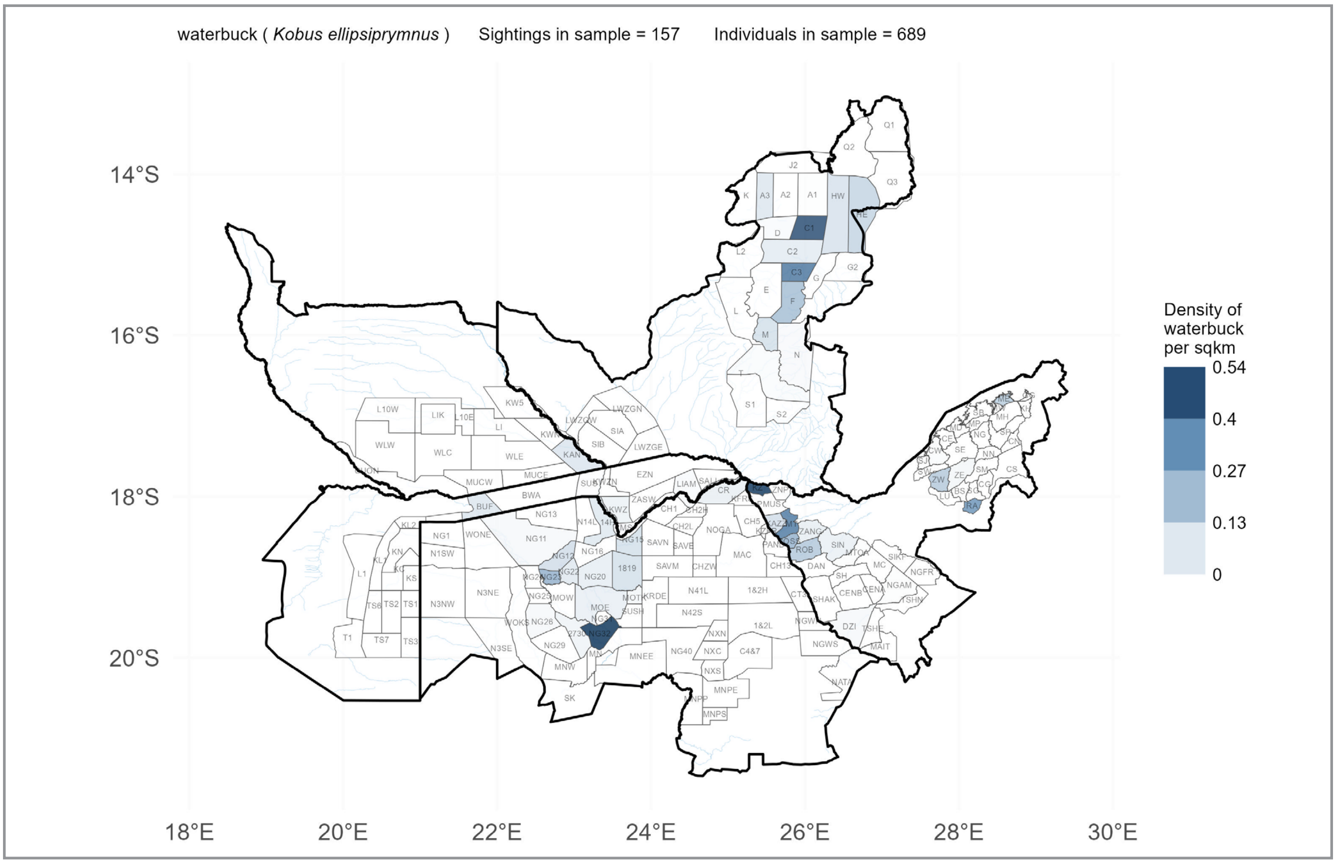


Figure 3.49: Estimated density of waterbuck in the KAZA TFCA survey area during the 2022 survey.

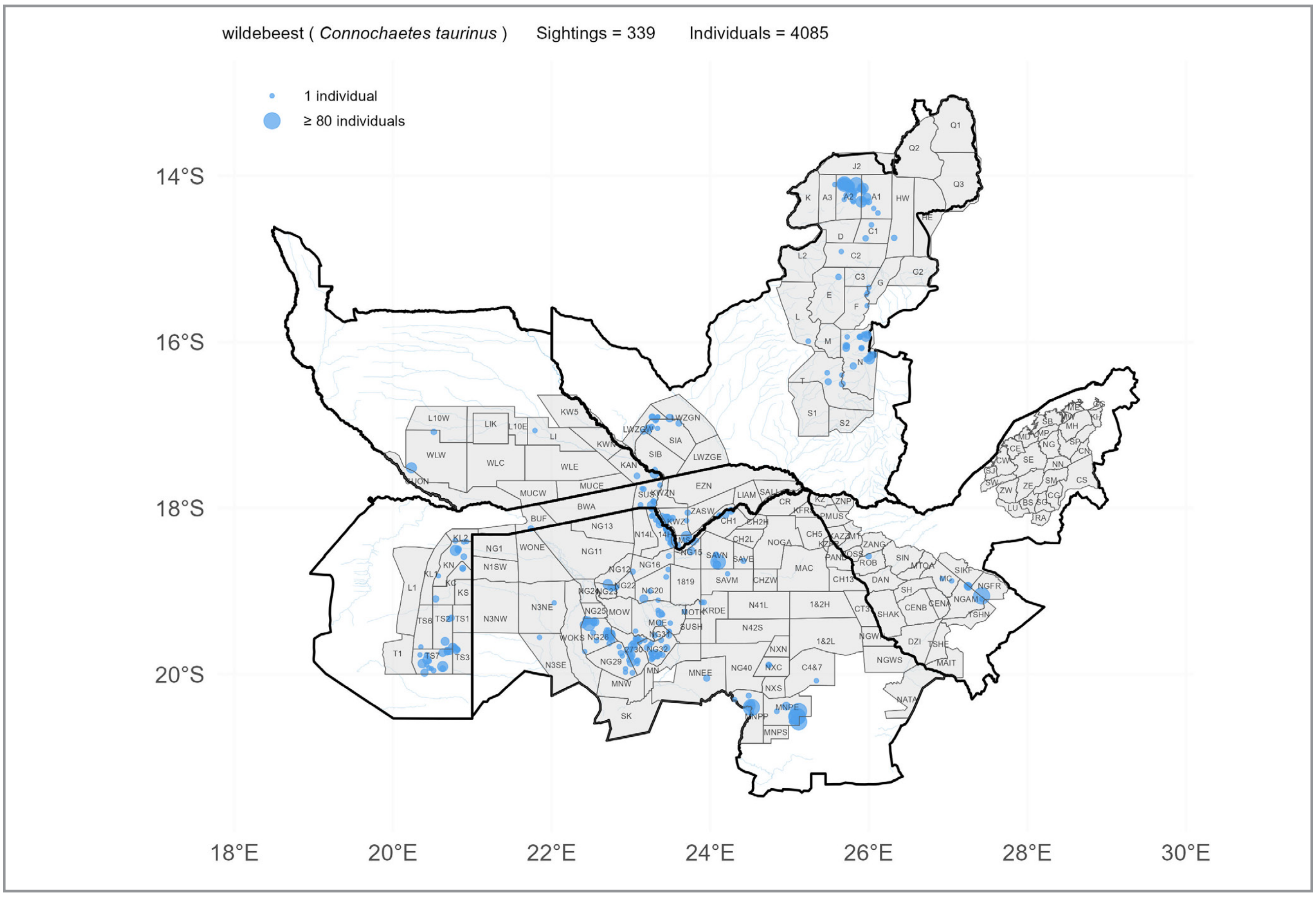


Figure 3.50: Spatial distribution of wildebeest observations in the KAZA TFCA survey area during the 2022 survey.

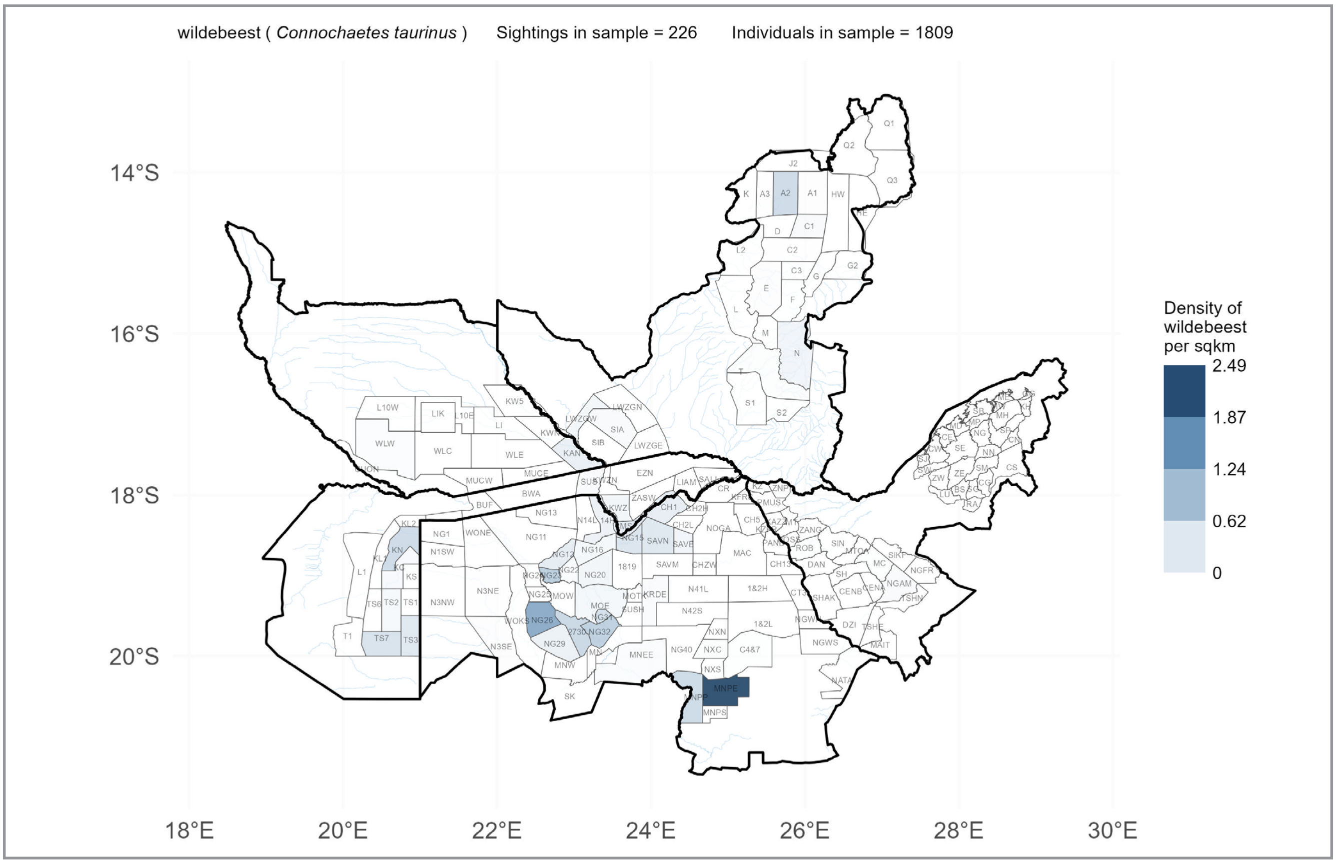


Figure 3.51: Estimated density of wildebeest in the KAZA TFCA survey area during the 2022 survey.

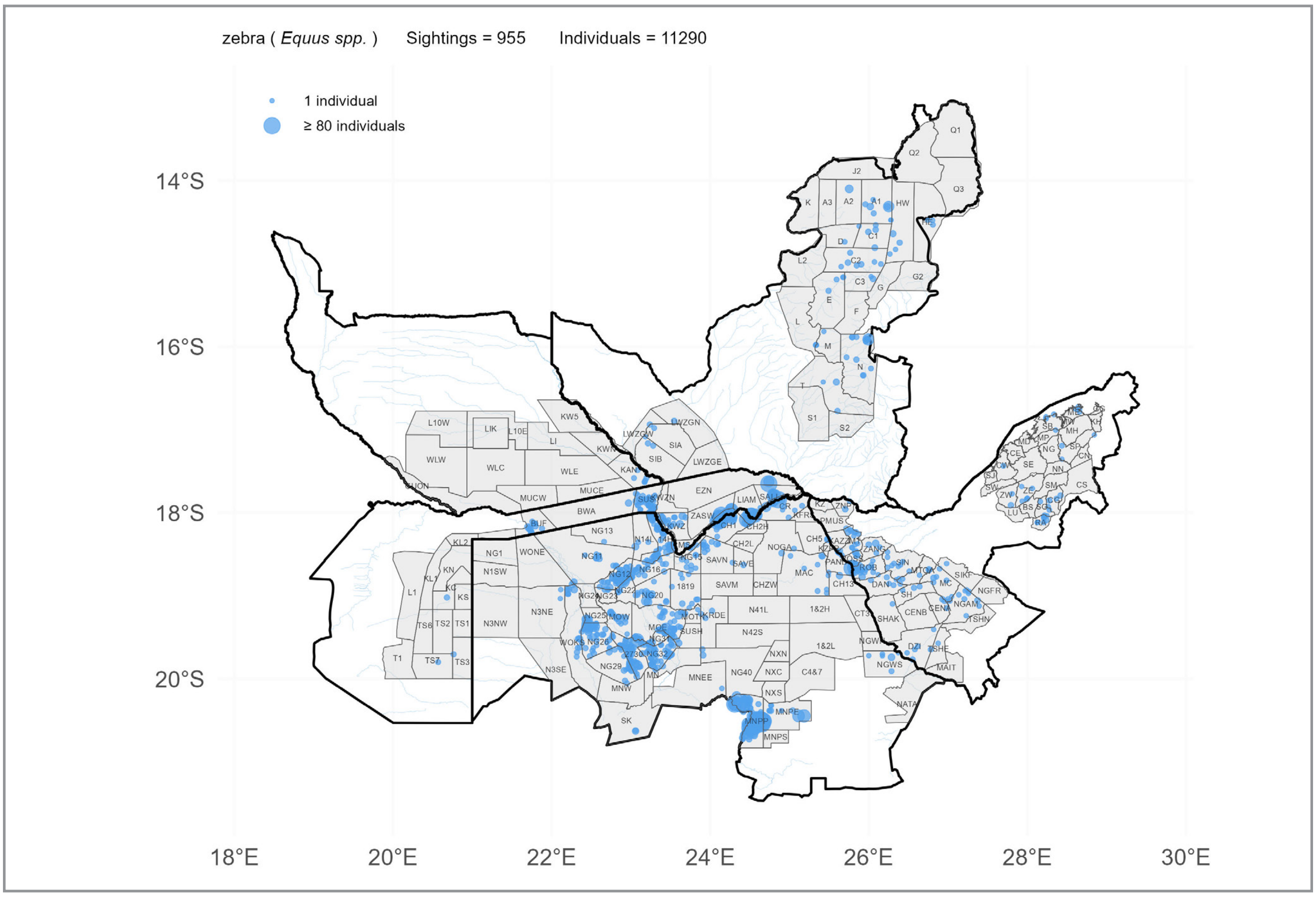


Figure 3.52: Spatial distribution of zebra observations in the KAZA TFCA survey area during the 2022 survey.

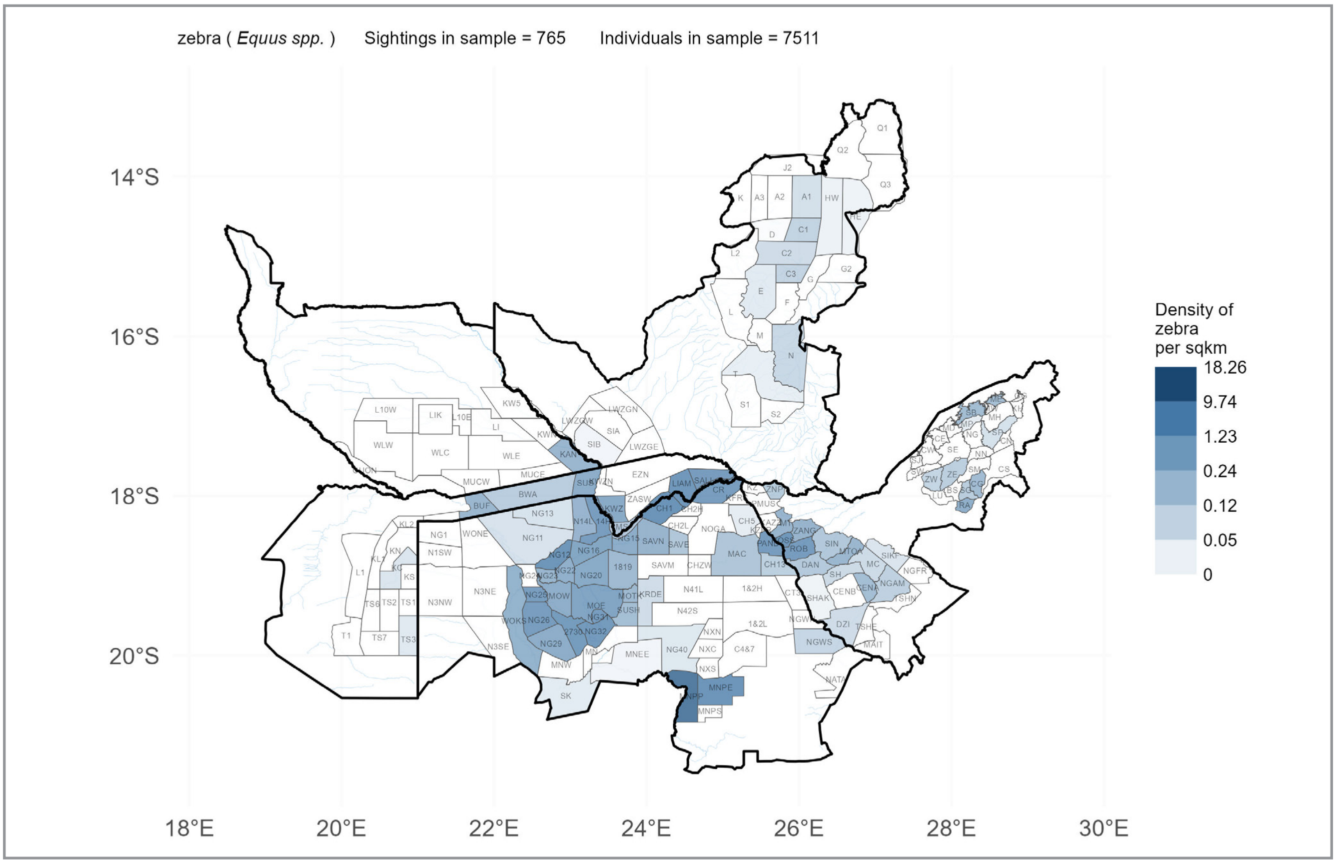


Figure 3.53: Estimated density of zebra in the KAZA TFCA survey area during the 2022 survey.

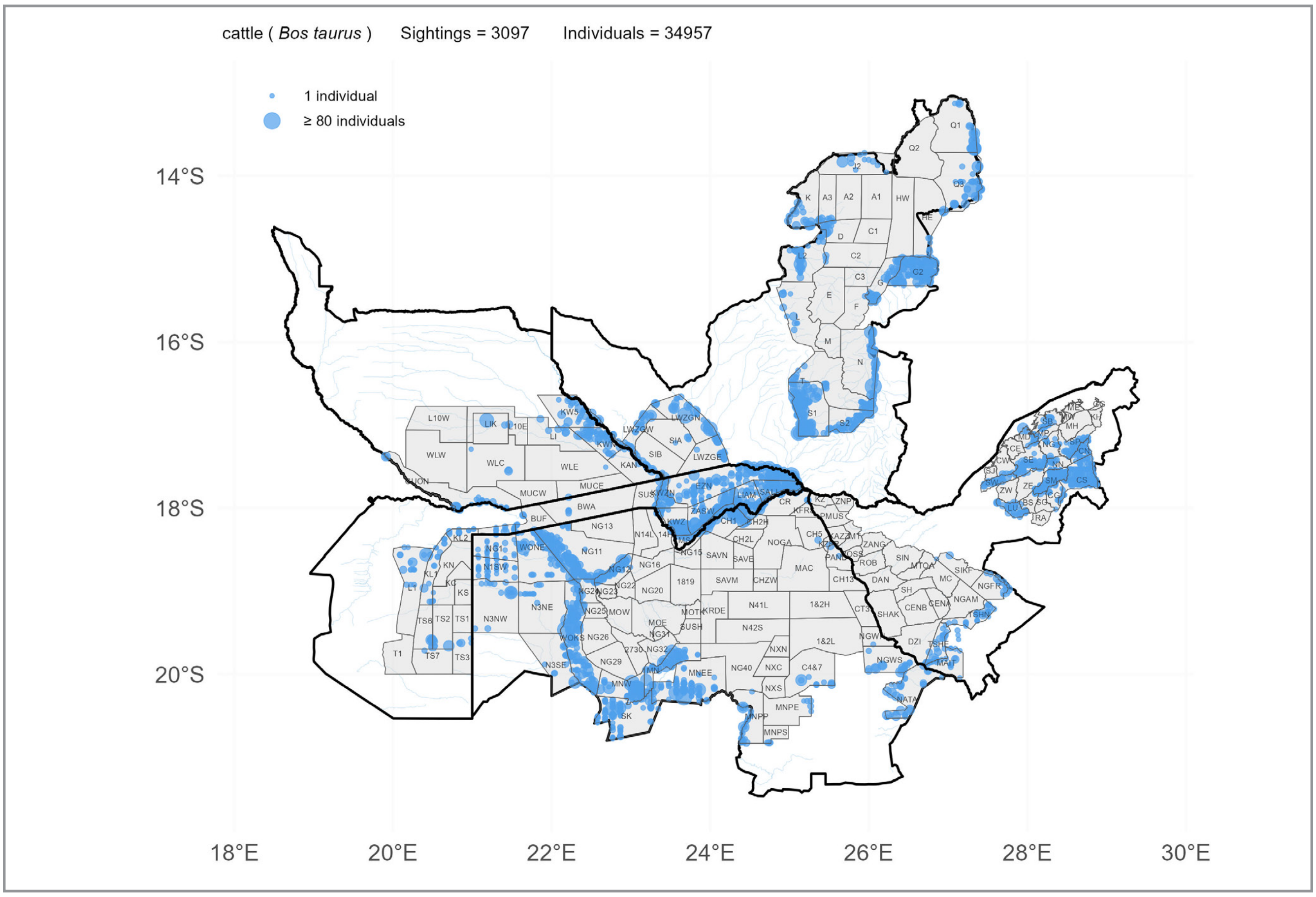


Figure 3.54: Spatial distribution of cattle observations in the KAZA TFCA survey area during the 2022 survey.

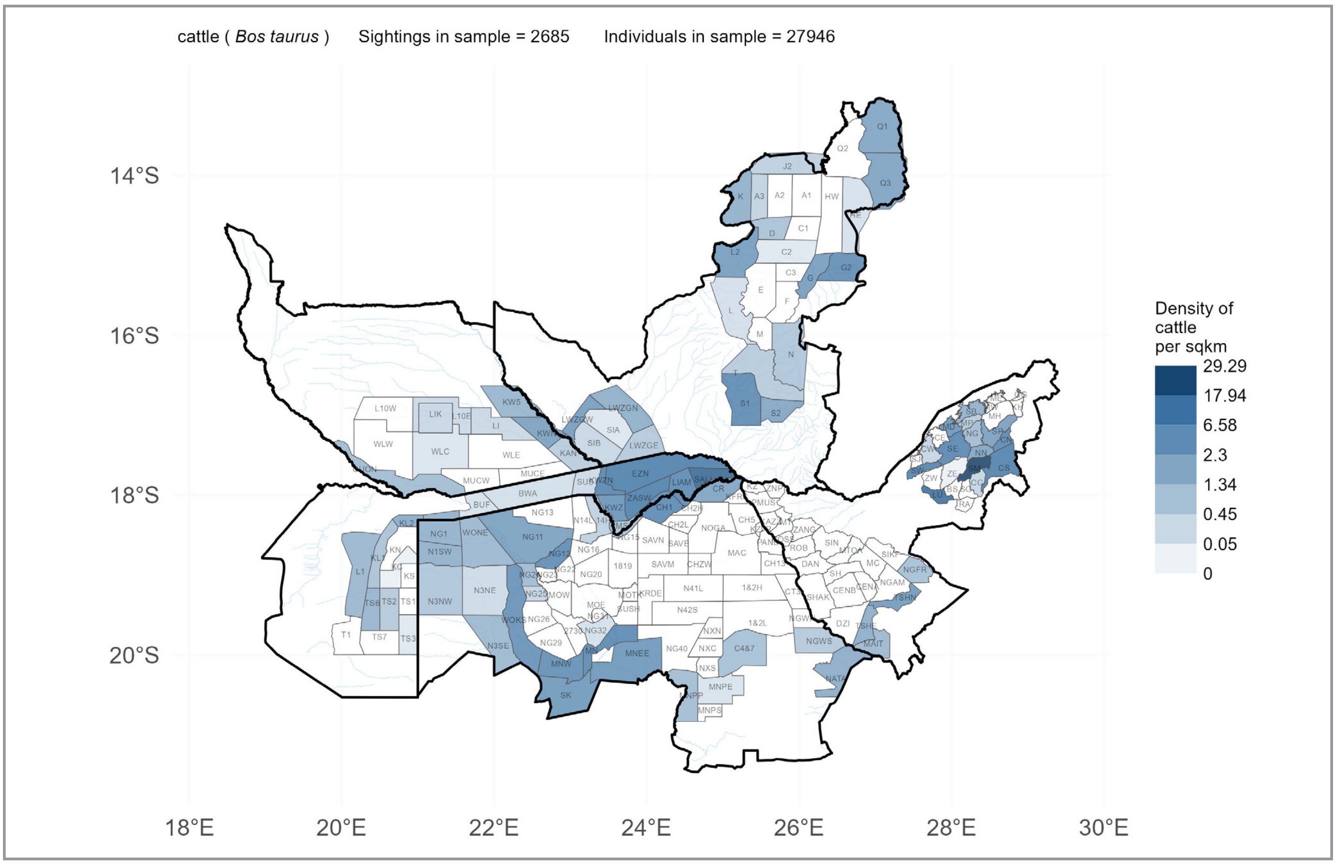


Figure 3.55: Estimated density of cattle in the KAZA TFCA survey area during the 2022 survey.

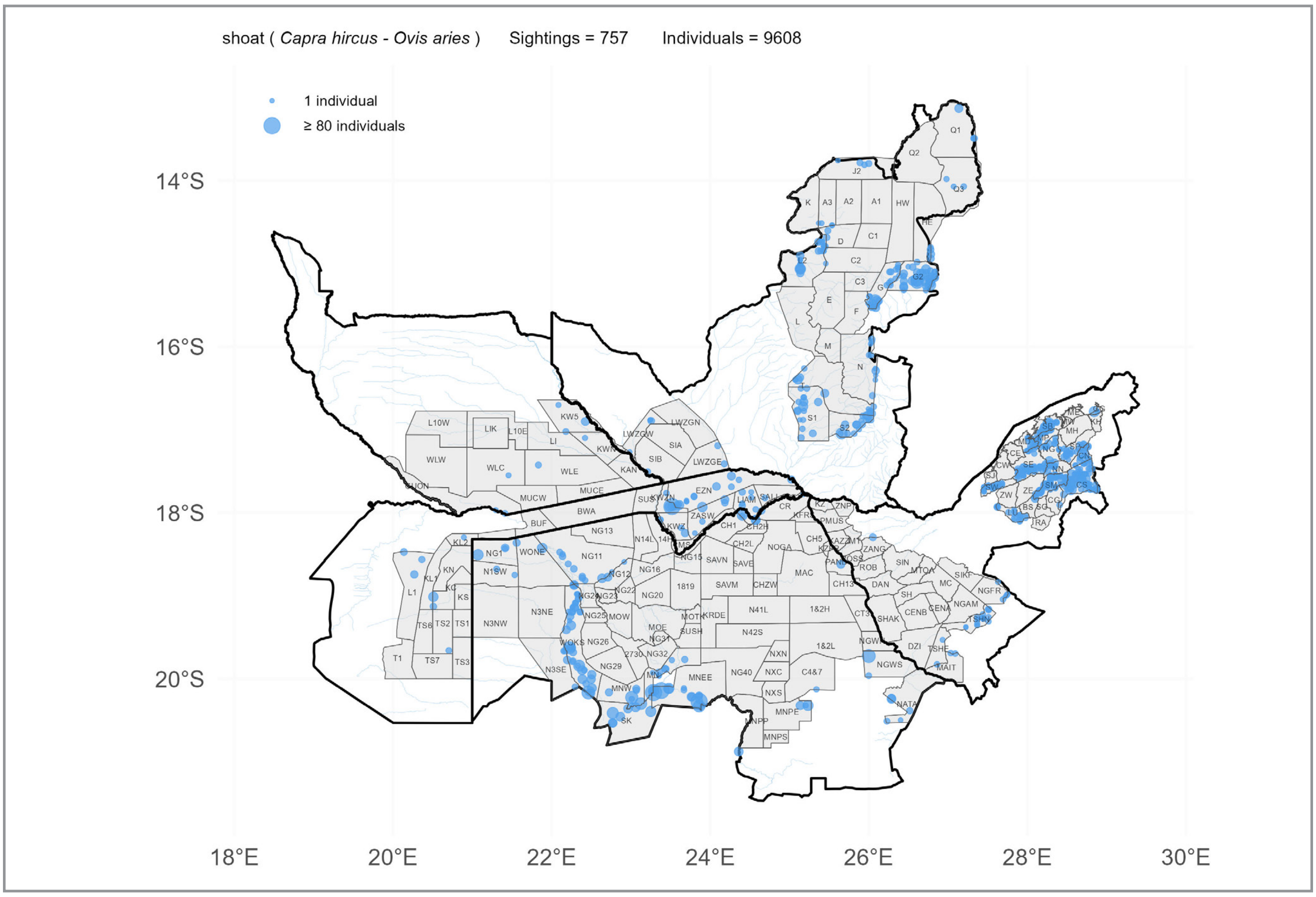


Figure 3.56: Spatial distribution of sheep and goat (shoat) observations in the KAZA TFCA survey area during the 2022 survey.

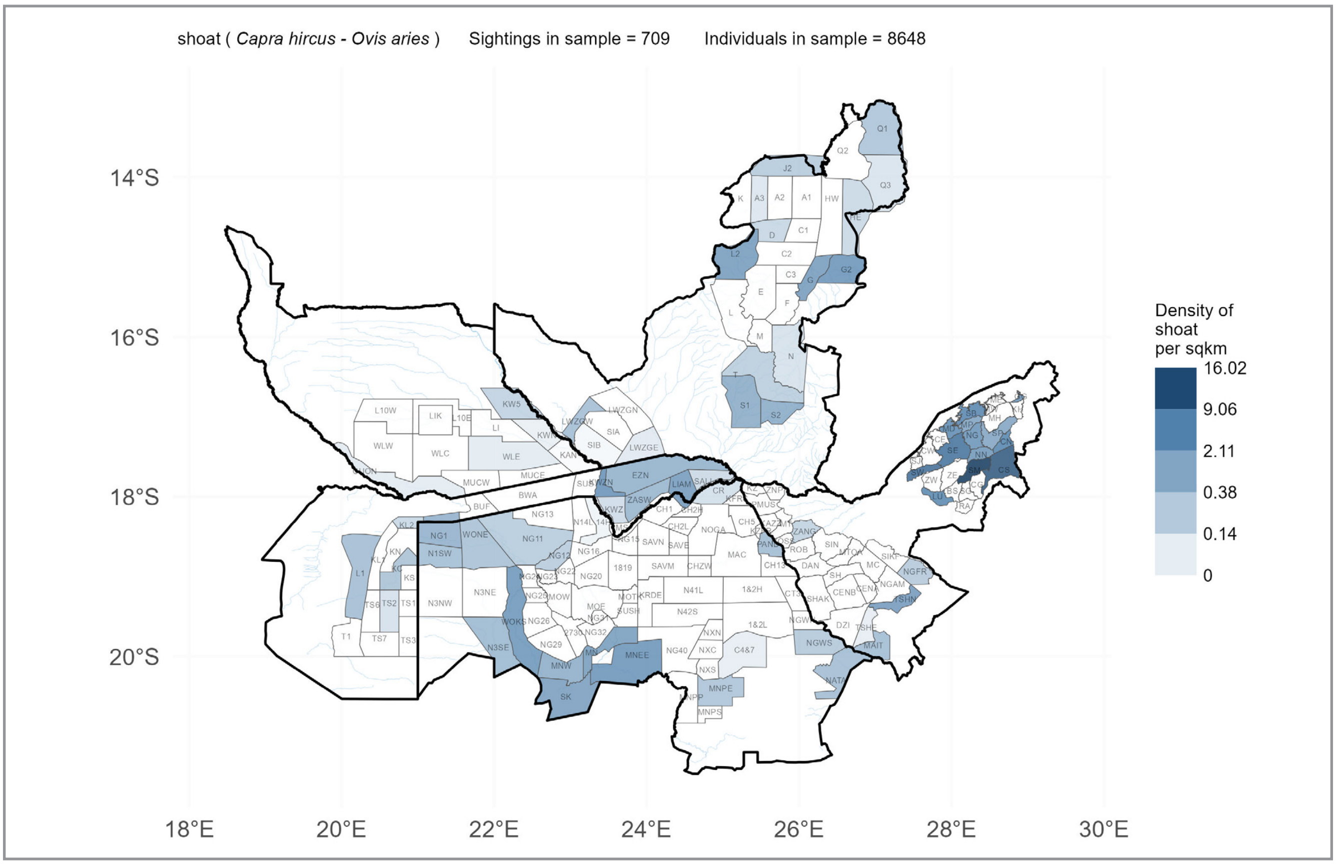


Figure 3.57: Estimated density of sheep and goats (shoats) in the KAZA TFCA survey area during the 2022 survey.

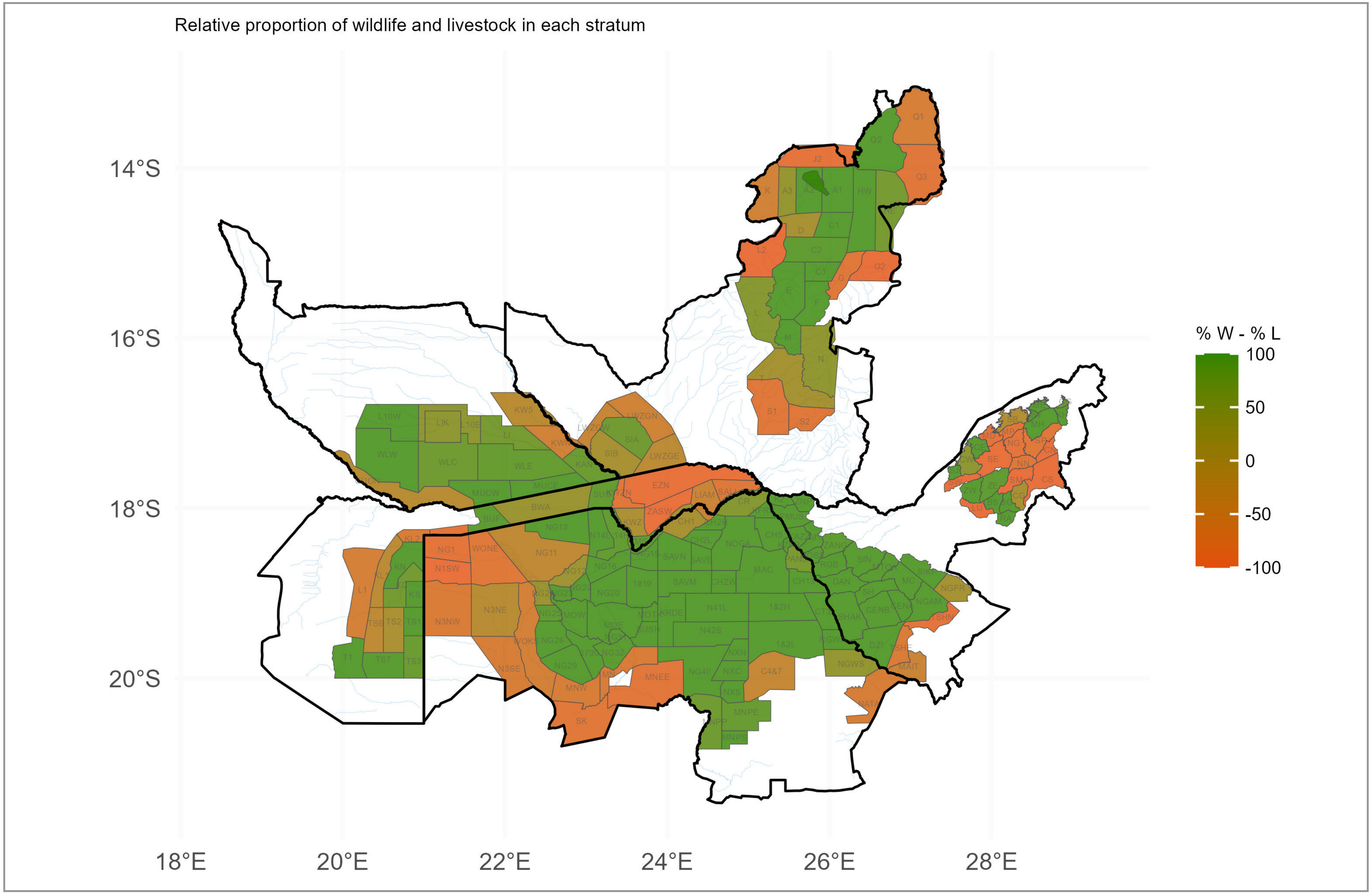


Figure 3.58: Relative abundance of wildlife and livestock across the KAZA TFCA survey area during the 2022 survey. Positive values indicate that the wildlife population estimate (sum of the population estimates for each wildlife species) is greater than that of livestock (green). Conversely, negative values indicate greater livestock abundance (orange).

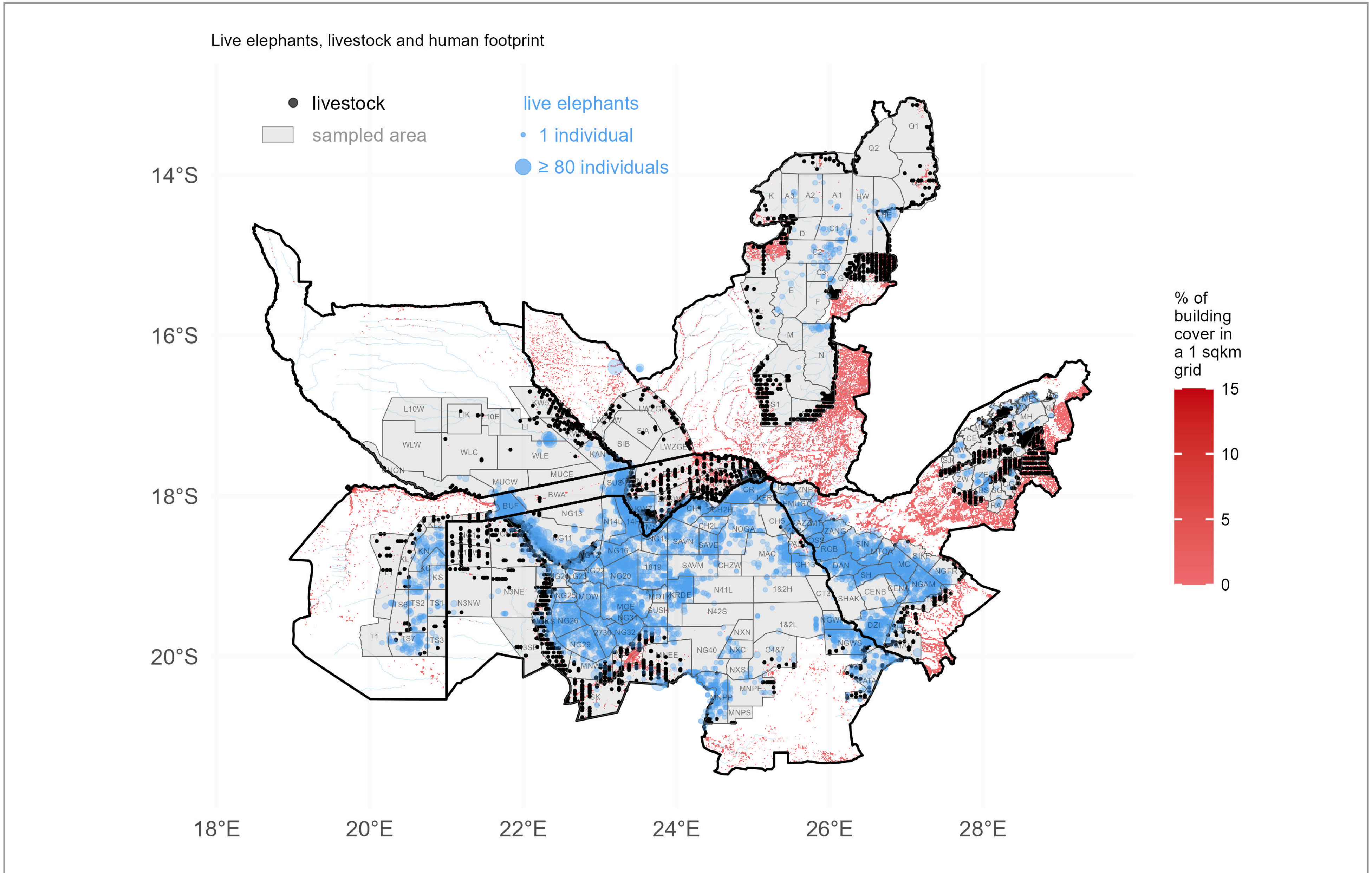


Figure 3.59: Spatial distribution of live elephants (bulls and family herds) and livestock observations in the KAZA TFCA survey area during the 2022 survey, overlayed on a human settlement density map created from the Open Buildings dataset (Sirko et al, 2021). .

Table 3.18: Detailed information of group size from observations made in the KAZA TFCA survey area.

Species	No of individuals seen	No of groups seen	Group size			
			Average	Min.	Max.	SD
Elephants						
all elephants	23615	3684	6.41	1	159	8.18
elephant bull	3005	1608	1.87	1	31	1.69
elephant family group	20610	2076	9.93	1	159	9.39
all elephant carcasses	2157	2115	1.02	1	4	0.15
C1-2 elephant carcasses	104	103	1.01	1	2	0.10
C3-4 elephant carcasses	2053	2012	1.02	1	4	0.15
elephant carcass one	29	29	1.00	1	1	0.00
elephant carcass two	75	74	1.01	1	2	0.12
elephant carcass three	780	755	1.03	1	4	0.21
elephant carcass four	1273	1257	1.01	1	2	0.11
Wildlife						
baboon	552	76	7.26	1	50	7.56
buffalo	8898	448	19.86	1	290	38.92
bushbuck	72	44	1.64	1	10	1.40
bushpig	100	36	2.78	1	8	2.09
duiker	952	849	1.12	1	3	0.35
eland	453	83	5.46	1	70	10.51
giraffe	1139	494	2.31	1	21	1.95
grysbok	14	9	1.56	1	6	1.67
hartebeest	1052	159	6.62	1	25	6.05
hippopotamus	1992	486	4.10	1	110	6.58
impala	11171	1013	11.03	1	259	14.77
klipspringer	4	2	2.00	2	2	0.00
kudu	1331	439	3.03	1	19	2.30
oribi	7	3	2.33	2	3	0.58
oryx	267	103	2.59	1	14	2.45
ostrich	436	223	1.96	1	16	2.04
puku	1410	183	7.70	1	48	8.29
red lechwe	14656	1684	8.70	1	312	13.52
reedbuck	348	167	2.08	1	11	1.38
roan	676	174	3.89	1	41	5.34
sable	3447	617	5.59	1	135	9.11
sitatunga	27	25	1.08	1	2	0.28
springbok	12	2	6.00	2	10	5.66
tsessebe	566	121	4.68	1	38	4.95
warthog	2526	817	3.09	1	15	2.24
waterbuck	689	157	4.39	1	25	4.52
wildebeest	1809	226	8.00	1	150	13.36
zebra	7511	762	9.86	1	230	18.42
Livestock						
cattle	27946	2685	10.41	1	154	13.07
donkey	1124	333	3.38	1	22	2.75
horse	213	60	3.55	1	18	3.05
shoat	8648	709	12.20	1	120	11.83

3.2 Speed of the sampling process

Most strata that required multiple flights were sampled using several aircraft flying synchronously during a single flight session. Nineteen strata required multiple flight sessions to complete the sampling; these are shown in Fig. 3.60 together with the number of days required to complete sampling each stratum.

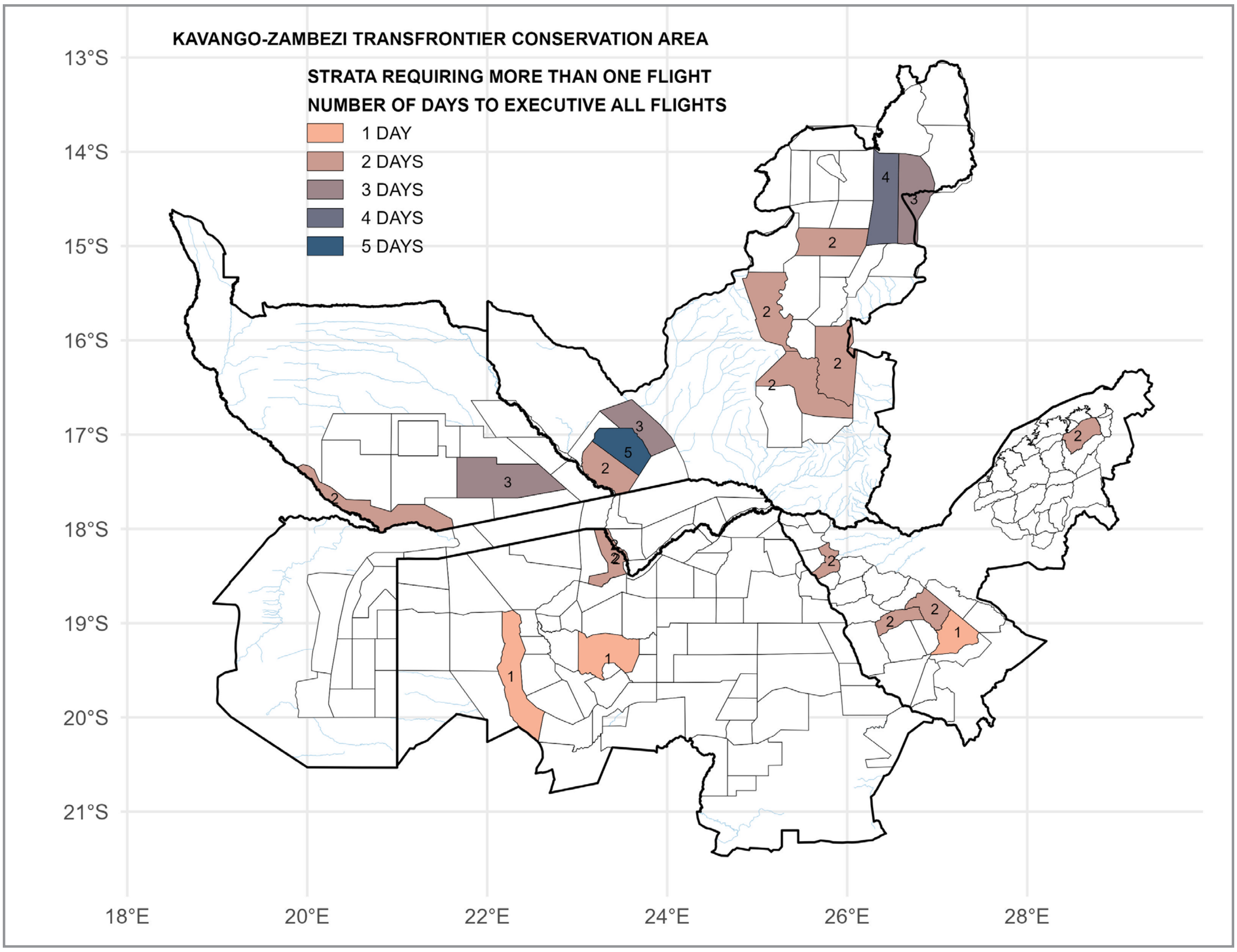


Figure 3.60: Number of days of flying to sample strata that required more than one flight session. The label in each stratum shows the number of days required to complete that stratum, where 1 means one day but multiple flight sessions.

- Four of the nineteen strata (i.e., 14H, MT, MC, and SH) required multiple flight sessions due to a repetition protocol being flown, where the flight repetitions were carried out at different times with equal sampling intensity and interleaved transects across the stratum.
- For three strata (i.e., WOKS, MOE and NGAM), part of the stratum was sampled during a first flight session in the morning, and the remainder in the afternoon of the same day.
- Seven strata were too large to be completed in one day and were thus flown over two days.
- Sampling of the remaining five strata was disrupted and delayed by logistical and technical challenges. Northeast of Kafue, only one of the two crews was permitted to enter the no-fly zone, making it impossible to synchronise the two aircraft to reduce the total sampling time of the HE and HW strata. At Sioma, where only one crew was mobilised, technical problems with the GPS and laser altimeter, and illness, forced the premature termination of some flights. Then, with the aircraft returning to Lusaka for a repair of the fuel system, and the remaining hours on the engine used up, it became impossible to fly the final stratum within the initial time frame, and it was completed later when an aircraft was available.

3.3 Synchronisation of the sampling process

Synchronisation efforts during sampling were prioritised for strata where elephant density and transboundary movements were expected to be higher. The average and maximum number of days between sampling a stratum and all its neighbouring strata are respectively presented in the left and right maps of Fig. 3.61. This is calculated based on the time elapsed, in days, between surveying a specific stratum and completing all the neighbouring strata. For further reference see Fig. 2. 6.

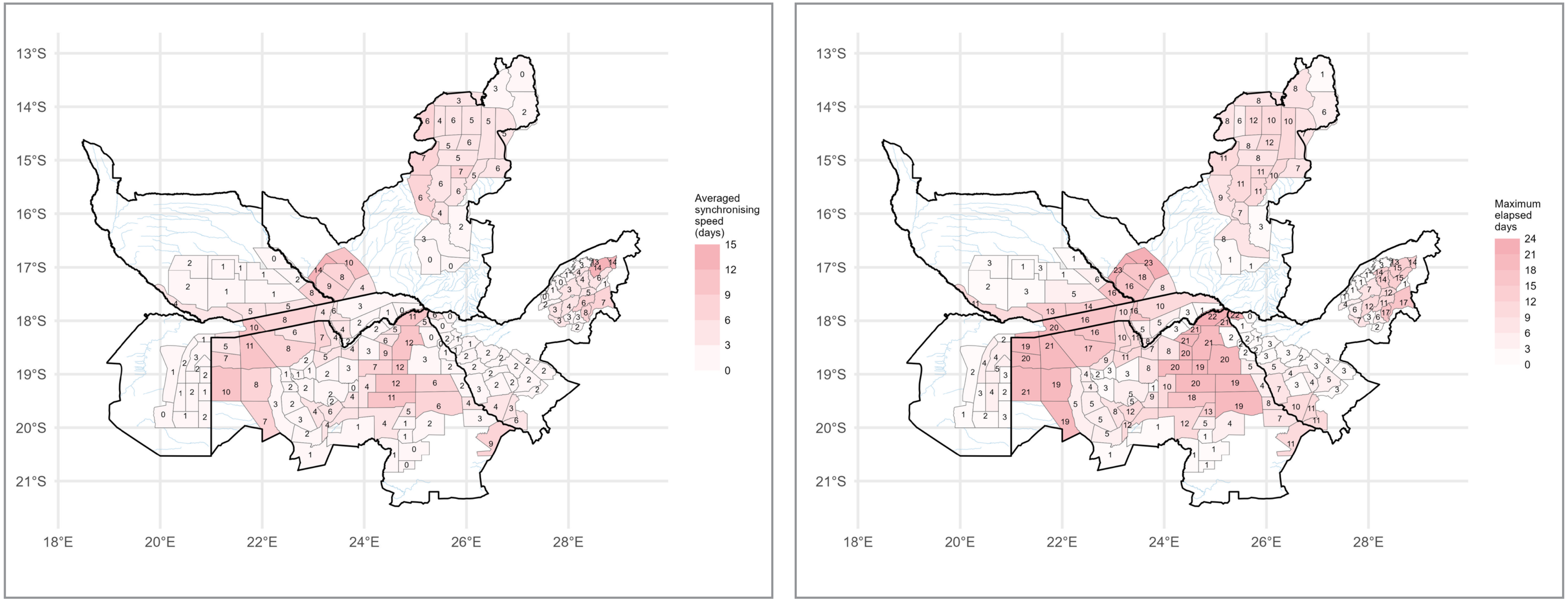


Figure 3.61: Synchronisation of strata sampling across the survey area. Average (left) and maximum (right) number of days between sampling a stratum and all its neighbouring strata. The strata appear whiter where their sampling was well synchronised with that of all neighbouring strata. Conversely, those that are darker red were less well synchronised.

3.4 Calibration

Calibration data were collected during pre-survey calibration exercises and opportunistically throughout the survey by some crews, mainly crew C05 and C07. A summary of the data collection process, including the number of sessions and passes are presented below in Table 3.19

Table 3.19: Sessions and passes made for each crew for the collection of calibration data.

Crew	Period	Airstrip	Date	Session	No of passes	Tot No of passes
C01	Pre-survey	Umtshibi	29/08	1	18	55
			29/08	2	10	
			30/08	3	24	
	Peri-survey	Matopi	16/09	1	1	
			17/09	2	2	
C02	Pre-survey	Umtshibi	02/09	1	6	39
			03/09	2	14	
			03/09	3	15	
	Peri-survey	Matopi	17/09	1	4	
C03	Pre-survey	Umtshibi	02/09	1	6	49
			02/09	2	4	
			02/09	3	10	
	Peri-survey	Umtshibi Matopi	03/09	1	5	
			04/09	2	15	
			04/09	3	6	
			16/09	4	3	
C04	Pre-survey	Kasane	01/10	1	19	19
C05	Pre-survey	Chunga	25/08	1	16	43
	Peri-survey	Chunga	26/08	1	2	
			27/08	2	2	
			29/08	3	2	
			30/08	4	2	
			01/09	5	2	
			03/09	6	2	
			05/09	7	2	
			10/09	8	4	
			12/09	9	2	
			15/09	10	4	
			18/09	11	3	
C06	Pre-survey	Sioma	27/10	1	11	22
			27/10	2	11	
C07	Pre-survey	Chunga	25/08	1	12	84
			25/08	2	15	
			25/08	3	14	
	Peri-survey	Chunga Sioma	27/08	1	2	
			29/08	2	2	
			30/08	3	2	
			31/08	4	2	
			01/09	5	2	
			03/09	6	2	
			04/09	7	2	
			10/09	8	2	
			11/09	9	2	
			12/09	10	2	
			13/09	11	2	
			15/09	12	4	
			05/10	13	2	
			06/10	14	3	
			07/10	15	3	
			10/10	16	3	
			11/10	17	3	
			12/10	18	3	
C08	Pre-survey	Rokari	21/08	1	20	20

3.4.1 Linear regressions per crew

Pre-survey calibration

A summary of the results of the simple and non-intercept linear regression analyses of the pre-survey calibration data for the eight different crews, and an assessment of adherence to the standards, are presented in Table 3.20.

Table 3.20: Results of simple linear regression analyses applied to pre-survey data (r^2 is the coefficient of determination and Int. is the intercept). The search strip width estimates are provided in meters. The RSE gives the relative standard error of the mean of the search strip width. Orange cells indicate instances where the CITES MIKE Standards were not met.

Crew	Side	Date	Passes	Simple linear regression				Forced through zero		RSE (%)
				r^2	Slope	Int.	Width	F. slope	F. Width	
C01	L	30/08/22	22	0,72	0,5210	15	171	0.5701	171	2,6
	R	30/08/22	22	0,83	0,4235	17	144	0.4804	144	2,2
	C	30/08/22	22	0,85	0,9445	32	316	1.0505	315	1,9
C02	L	03/09/22	35	0,77	0,5235	4	161	0.5370	161	2,2
	R	03/09/22	35	0,31	0,3921	37	155	0.5163	155	4,3
	C	03/09/22	35	0,65	0,9156	41	316	1.0533	316	2,5
C03	L	02/09/22	10	0,72	0,5765	-17	156	0.5167	155	6,8
	R	02/09/22	10	0,82	0,4917	8	155	0.5190	156	3,7
	C	02/09/22	10	0,80	1,0682	-9	311	1.0357	311	4,7
C04	L	02/10/22	19	0,31	0,2764	68	151	0.5102	153	3,7
	R	02/10/22	19	0,72	0,5302	-5	154	0.5126	154	2,5
	C	02/10/22	19	0,69	0,8066	63	305	1.0228	307	2,3
C05	L	25/08/22	16	0,78	0,4677	15	155	0.5238	157	3,9
	R	25/08/22	16	0,85	0,4421	13	146	0.4913	147	3,0
	C	25/08/22	16	0,86	0,9099	28	301	1.0151	305	3,1
C06	L	27/10/22	22	0,75	0,5549	-30	136	0.4594	138	4,1
	R	27/10/22	22	0,82	0,4646	21	160	0.5290	159	2,2
	C	27/10/22	22	0,82	1,0195	-10	296	0.9884	297	2,4
C07	L	26/08/22	14	0,79	0,4880	7	154	0.5135	154	2,7
	R	26/08/22	14	0,71	0,4343	25	156	0.5243	157	2,8
	C	26/08/22	14	0,77	0,9224	32	309	1.0378	311	2,6
C08	L	21/08/22	20	0,66	0,4704	0	142	0.4720	142	3,3
	R	21/08/22	20	0,87	0,4031	28	149	0.4987	150	1,7
	C	21/08/22	20	0,87	0,8735	28	290	0.9707	291	1,7

Further details of these analyses are presented using six graphical panels per crew in Fig. 3.62 to Fig. 3.69. The left, right and combined observer results are presented from left to right. The linear regressions are in the first row, while in the second row, the distribution of strip width measurements relative to the height of 300 ft (91 m) is represented by a whisker box plot[6], along with the relative standard error of the mean.

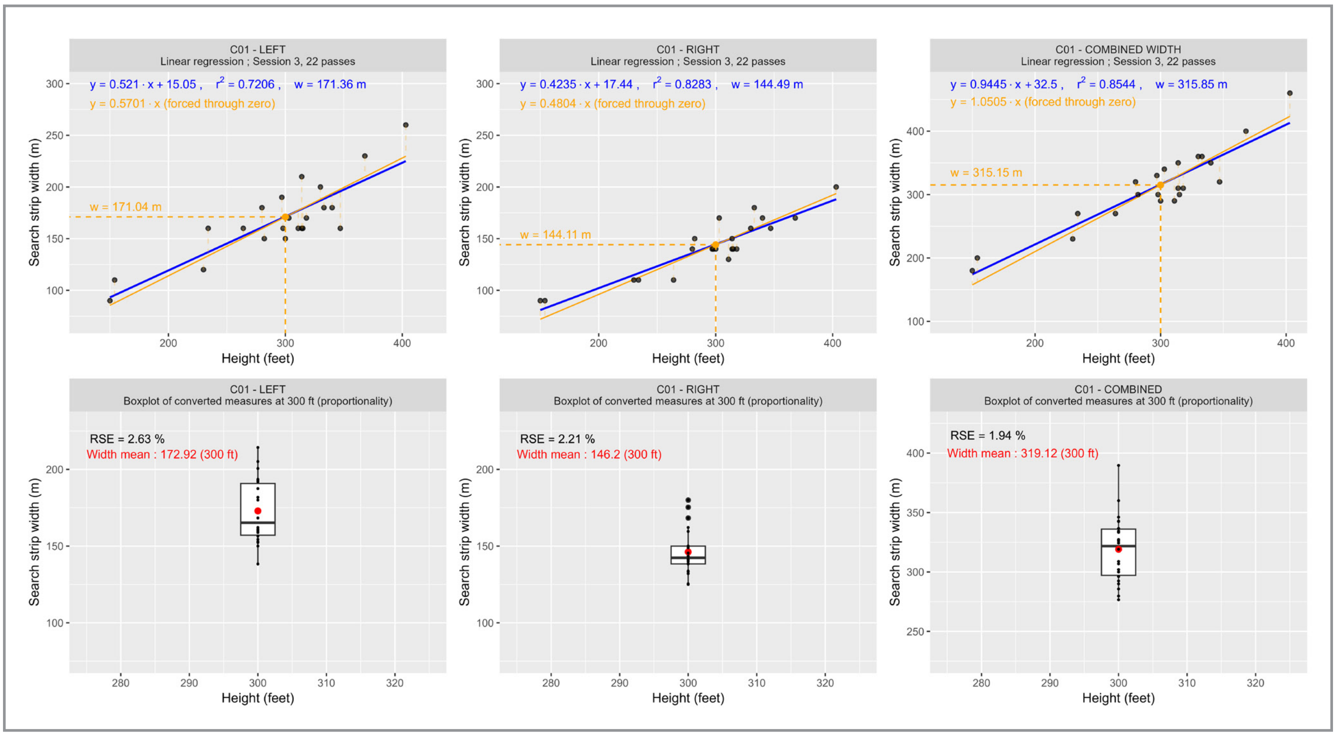


Figure 3.62: Details of the linear regression analyses and graphical representations for crew C01.

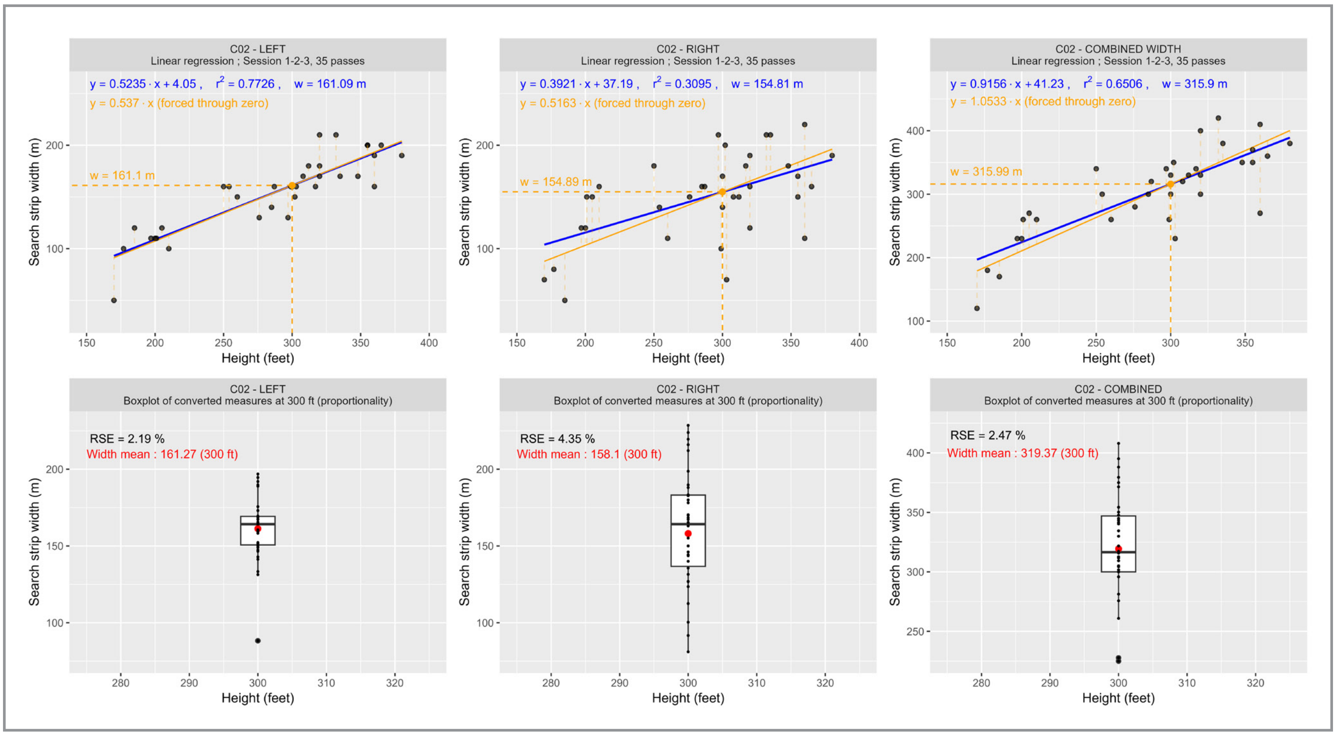


Figure 3.63: Details of the linear regression analyses and graphical representations for crew C02.

[6] *A whisker box plot displays a graphical representation of the five-number summary, including the minimum, first quartile, median, third quartile, and maximum of a dataset. It provides insights into the distribution of the data, including its central tendency, dispersion, and skewness*

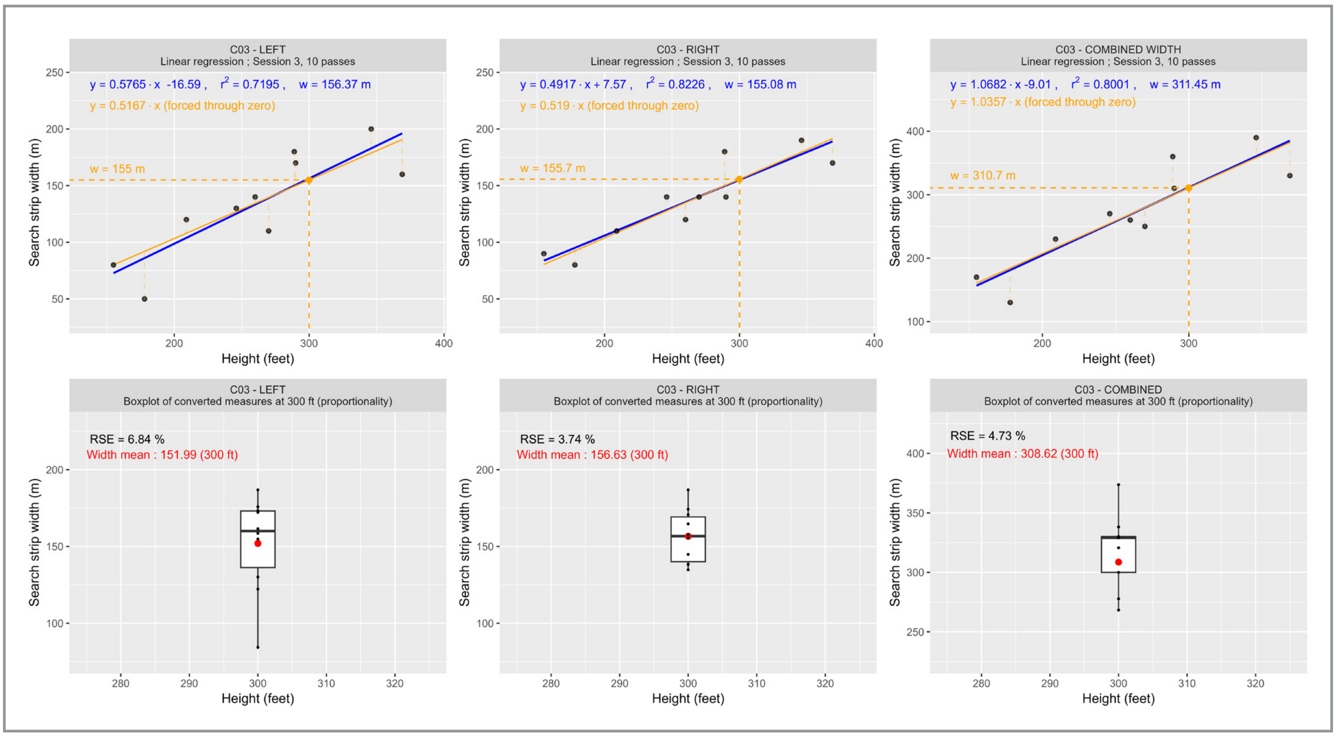


Figure 3.64: Details of the linear regression analyses and graphical representations for crew C03.

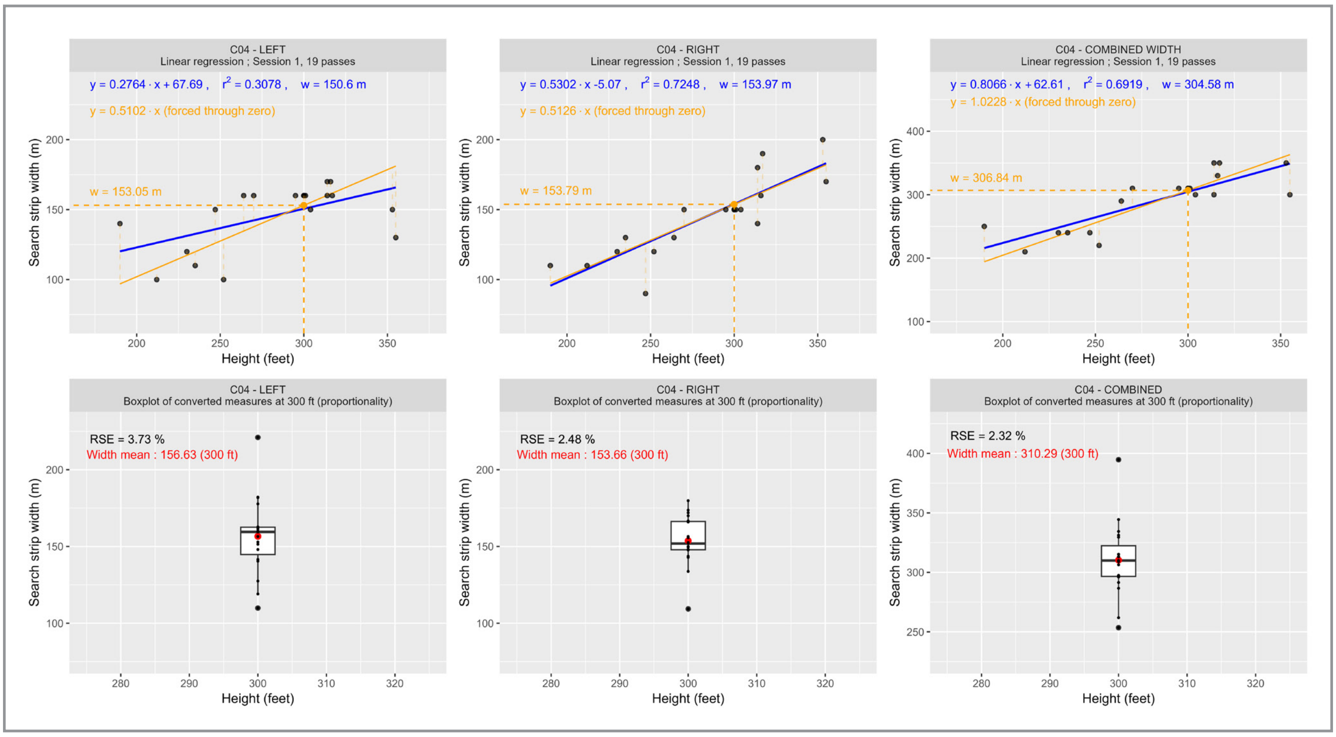


Figure 3.65: Details of the linear regression analyses and graphical representations for crew C04.

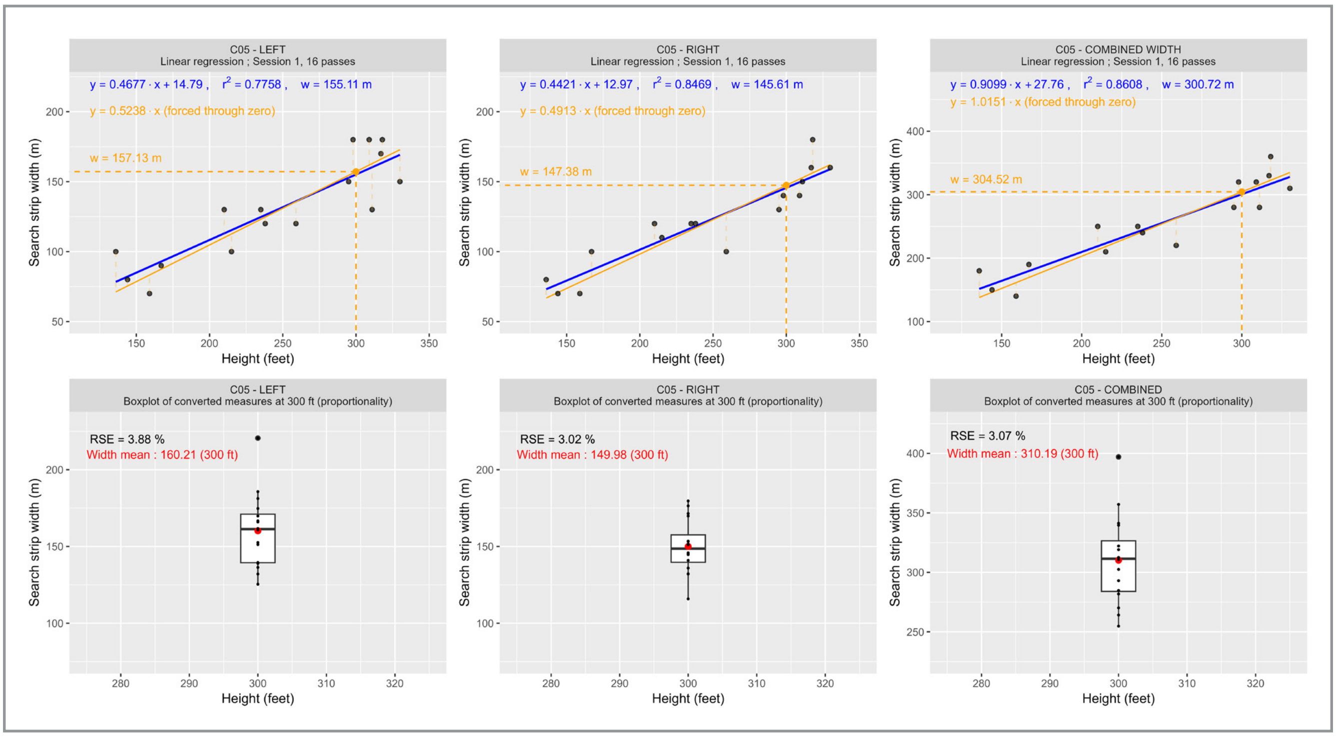


Figure 3.66: Details of the linear regression analyses and graphical representations for crew C05.

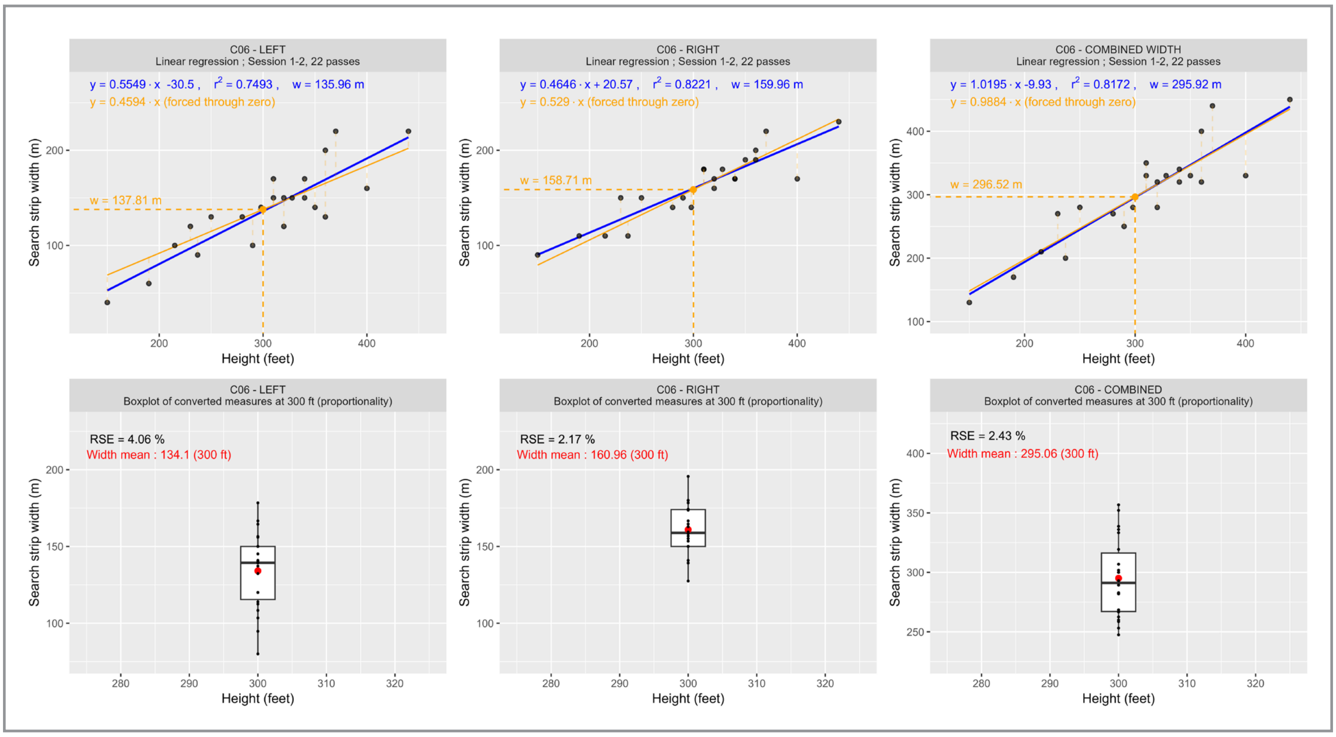


Figure 3.67: Details of the linear regression analyses and graphical representations for crew C06.

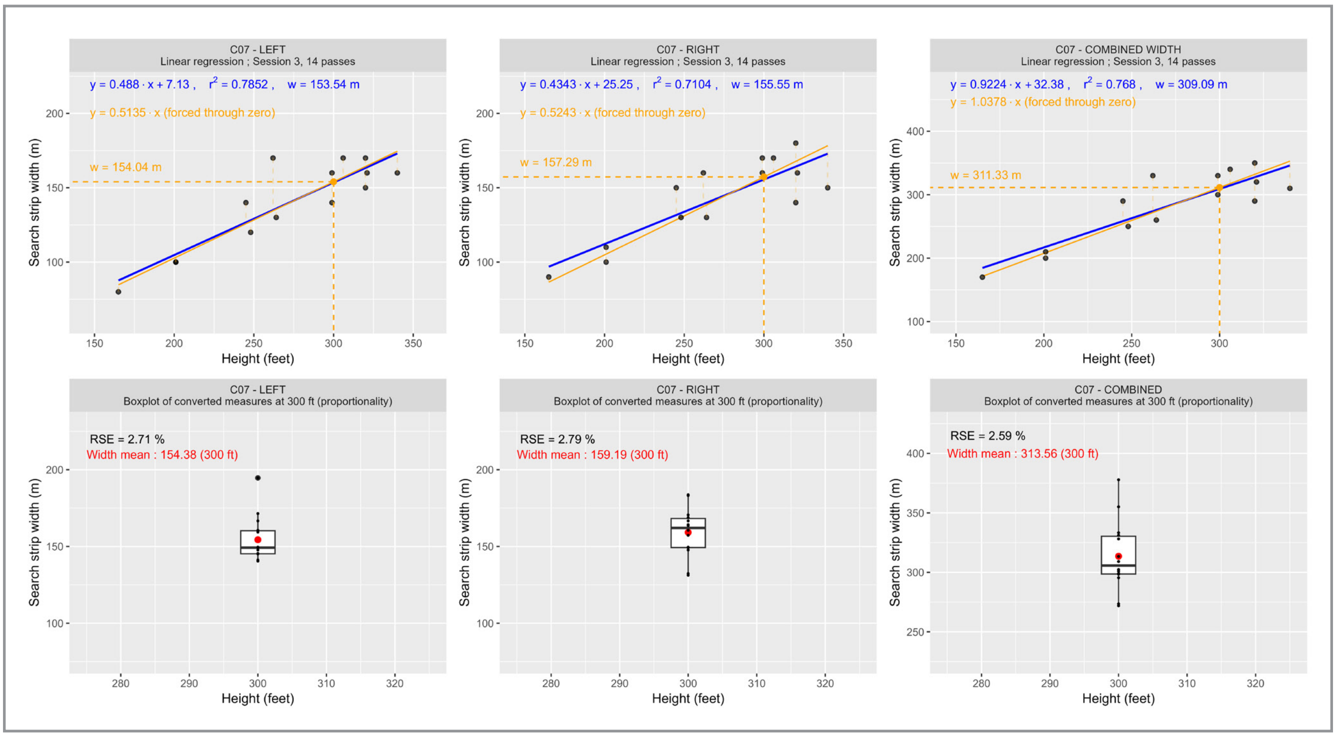


Figure 3.68: Details of the linear regression analyses and graphical representations for crew C07.

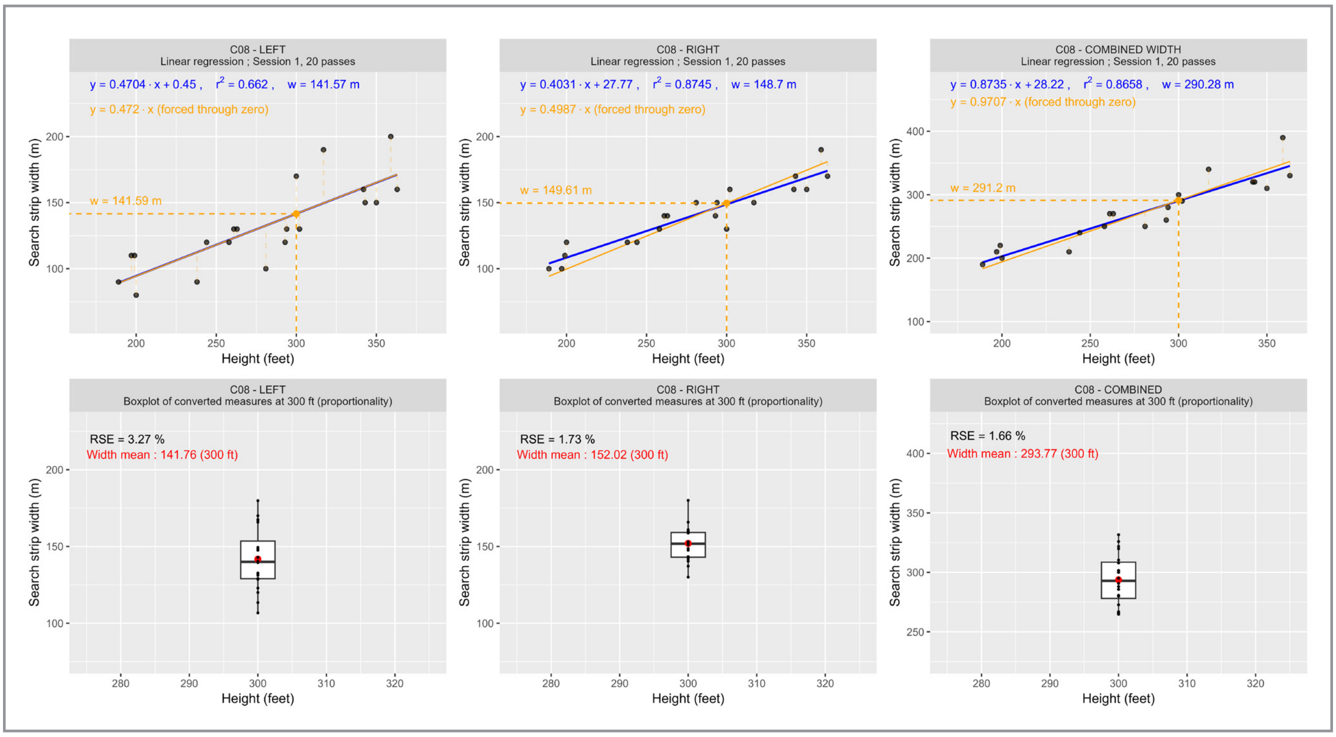


Figure 3.69: Details of the linear regression analyses and graphical representations for crew C08.

Peri-survey calibration

Results of the simple and non-intercept linear regression analyses of the peri-survey calibration data for crew C05 and C07, and an assessment of crew adherence to the standards, are presented in Table 3.21.

Table 3.21: Results of linear regression analyses applied to peri-survey data (r^2 is the coefficient of determination and Int. is the intercept). The search strip width estimates are provided in meter. The RSE gives the relative standard error of the mean of search strip width. Orange cells indicate the CITES MIKE Standards were not met.

Crew	Side	Passes	Simple linear regression				Forced through zero		RSE (%)
			r^2	Slope	Int.	Width	F. slope	F. Width	
C05	L	27	0.80	0.5125	2	156	0.5205	156	2.0
	R	27	0.53	0.4059	30	152	0.5143	154	3.0
	C	27	0.84	0.9184	32	308	1.0348	310	1.4
C07	L	43	0.61	0.4836	-8	137	0.4568	137	1.8
	R	43	0.49	0.3992	15	135	0.4499	135	2.0
	C	43	0.66	0.8828	7	272	0.9067	272	1.5

The details of these analyses and their graphical representations are presented below in Fig. 3.70 and Fig. 3.71 with a series of six panels for both crews. The left, right and combined observer results are presented from left to right. The linear regressions are in the first row, while in the second row, the distribution of strip width measurements relative to the height of 300 ft (91 m) is represented by a whisker box, along with the relative standard error of the mean.

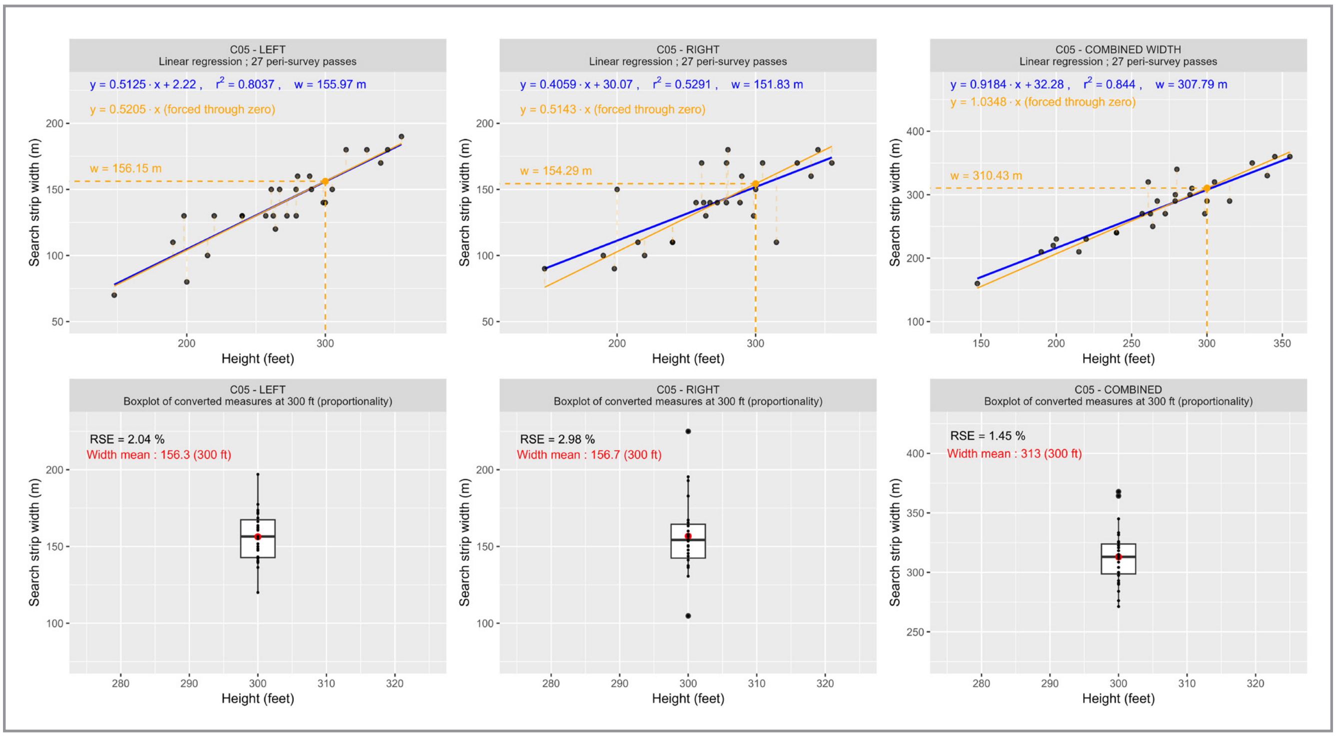


Figure 3.70: Details of the linear regression analyses and graphical representations for crew C05, using pre-survey calibration data.

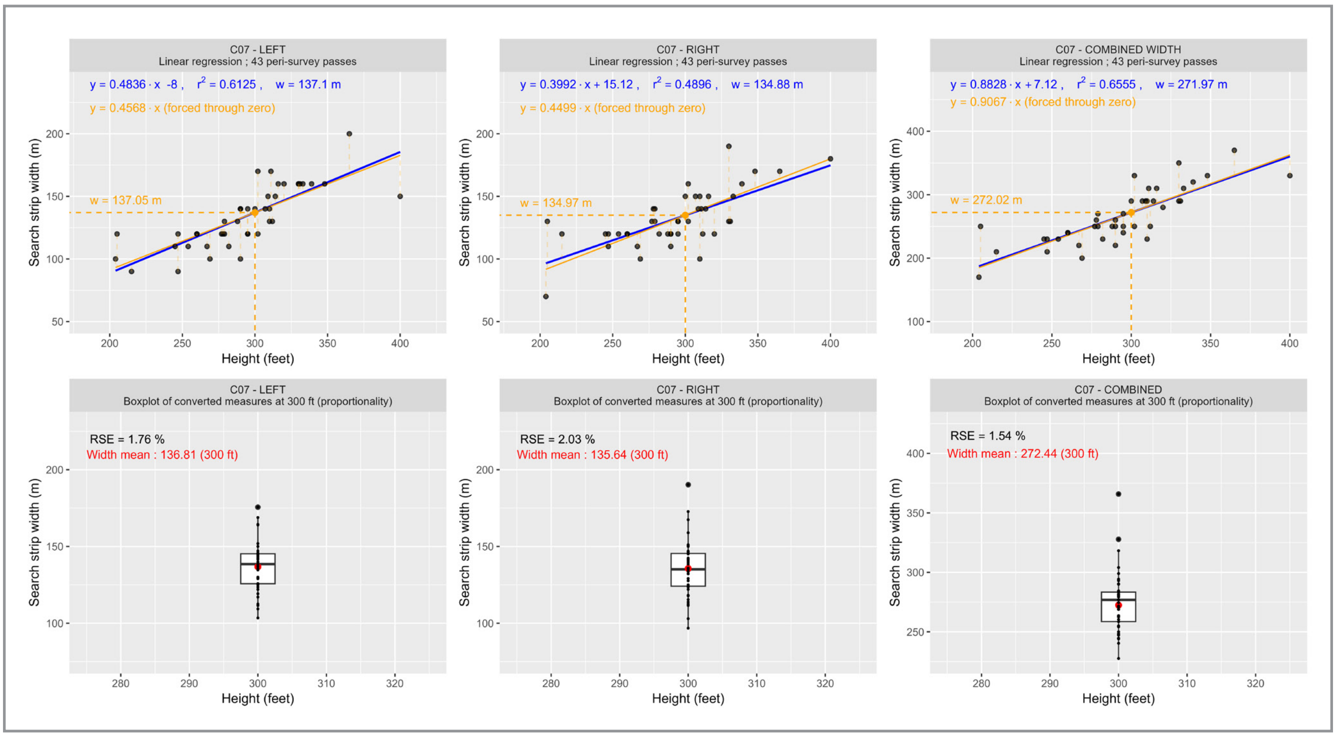


Figure 3.71: Details of the linear regression analyses and graphical representations for crew C07, using pre-survey calibration data.

3.4.2 Bootstrapping analysis of potential strip width variability

The number of simulated samples used for each crew in the bootstrapping analysis, and the range of potential variability of the search strip width (defined by the forced slope), are presented in Table 3.22. They serve to estimate the potential variability in search strip width estimates based on all calibration passes performed. This analysis was not conducted for C04 and C08 due to the limited number of passes. Additional data subsets were added to include calibration data from all passes, each session, and selected passes for pre-survey calibration. These data subsets explain why despite no bootstrapping analysis was performed for C06, minimum and maximum forced slopes were derived.

The impact that such search strip width variability would have on elephant population estimates at the KAZA TFCA scale is presented in Table 3.23. The results are given for the minimum and maximum potential values at 300 feet mean flying height, i.e., 281 m and 324 m strip width.

Table 3.22: Forced slope values derived from the bootstrapping analysis.

Crew	Side	Selected forced slope	Nb of simulated samples	Data subsets	Minimum forced slope	Maximum forced slope	Variability range
C01	L	0.5701	720	5	0.5268	0.6329	0.11
	R	0.4804			0.3979	0.5325	0.13
	C	1.0505			0.9651	1.1050	0.14
C02	L	0.5370	440	4	0.5120	0.5864	0.07
	R	0.5163			0.4445	0.6142	0.17
	C	1.0533			0.9713	1.1569	0.19
C03	L	0.5167	620	4	0.3410	0.5167	0.18
	R	0.5190			0.4787	0.5733	0.09
	C	1.0357			0.8583	1.0357	0.18
C04	L	0.5102		1	-	-	-
	R	0.5126			-	-	-
	C	1.0228			-	-	-
C05	L	0.5238	480	3	0.4866	0.5583	0.07
	R	0.4913			0.4705	0.5490	0.08
	C	1.0151			0.9899	1.0938	0.10
C06	L	0.4594		4	0.4365	0.4910	0.05
	R	0.5290			0.5180	0.5443	0.03
	C	0.9884			0.9545	1.0353	0.08
C07	L	0.5135	1300	5	0.3656	0.5135	0.15
	R	0.5243			0.3208	0.5243	0.20
	C	1.0378			0.6864	1.0378	0.35
C08	L	0.4720		1	-	-	-
	R	0.4987			-	-	-
	C	0.9707			-	-	-

Table 3.23: Impact that potential variability in the search strip width estimate may have on the elephant population estimates calculated for the KAZA TFCA.

Zone	Species	Width	Pop. Estimate	CI	95% Confidence Range			PRP	No Seen		Variance
					LCL		UCL		In	Out	
KAZA	all elephants	281	252451	±16743	235708	-	269194	6.6%	23615	38877	89390371
	all elephants	310	227900	±16743	211157	-	244643	7.3%	23615	38877	72191578
	all elephants	324	217501	±16743	200758	-	234244	7.7%	23615	38877	65198787

3.5 Crew Performance

Search effort averaged 1.12 minutes.km^{-2} for the entire survey area and varied between 1.0 and 1.3 km^{-2} for individual strata. Further details are provided in Table A11.1 in Appendix 11.

3.5.1 Pilots

Ten pilots flew a total of 195 flights to sample 179 strata (excluding the red lechwe count). This resulted in a total of 700 flight hours, of which 57% was spent collecting standardised data along 2404 transects totalling 67390 km in length. On average, transects were flown at:

- an average height of 91.8 m AGL, with a standard deviation of 6.5 m,
- an average speed of 171.5 km.h^{-1}, with a standard deviation of 5.8 km.h^{-1}.

The flight effort and performance details for each pilot involved in systematic transect sampling is given in Table 3.24. The histograms of flight height and speed are presented in Fig. 3.72 to Fig. 3.80.

Table 3.24: Flight effort split and performance details for all pilots (unit for height is m, and speed is km.h^{-1}). Pilot 09 used block sampling methodology for two strata in Sebungwe, Zimbabwe.

Pilot	Flights	Strata	Transects number and length (km)					Flying hours	Sampling hours	Mean Height per transect	SD Height per transect	Mean Speed per transect	SD Speed per transect	Percentage of transects flown under optimal conditions			
			No	Length	Min	Max	Mean							Mean Hgt per transect	SD Hgt per transect	Mean Spd per transect	SD Spd per transect
P01	39	46	456	12937	0.7	67.1	28.4	159.3	75	92.1	4.5	171.8	4.4	98 %	95 %	98 %	99 %
P02	44	47	555	15238	0.7	91.4	27.5	173.8	87.8	92.3	5	173	4.9	99 %	93 %	98 %	98 %
P03	45	48	566	15596	1.8	72.9	27.6	177.5	91.8	92.5	4.9	169.8	5.3	99 %	97 %	96 %	97 %
P04	10	10	111	3557	4.7	63.1	32	39.3	20.5	88.2	8.5	172.8	8.2	100 %	63 %	98 %	83 %
P05	13	9	159	5393	3.5	66.7	33.9	63.6	30.7	90.3	6.7	174.8	8.1	100 %	87 %	96 %	83 %
P06	16	24	277	4626	0.3	53.4	16.7	85.4	27.5	92.2	13.5	170.4	8.5	94 %	18 %	92 %	58 %
P07	13	12	140	5095	5.4	72.4	36.4	48.6	29.9	91.1	6.3	170	6.1	99 %	96 %	99 %	90 %
P08	12	9	127	4731	5.1	67.3	37.3	52.2	27.7	89.8	6	170.2	5	100 %	93 %	100 %	99 %
P09	2	2															
P10	1	1	13	217	11.6	29.1	16.7	2.8	1.2	92.4	4.4	173.6	3	100 %	100 %	100 %	100 %
All pilots	195	179	2404	67390	0.3	91.4	28	699.8	398.2	91.8	6.5	171.5	5.8	99 %	84 %	97 %	91 %

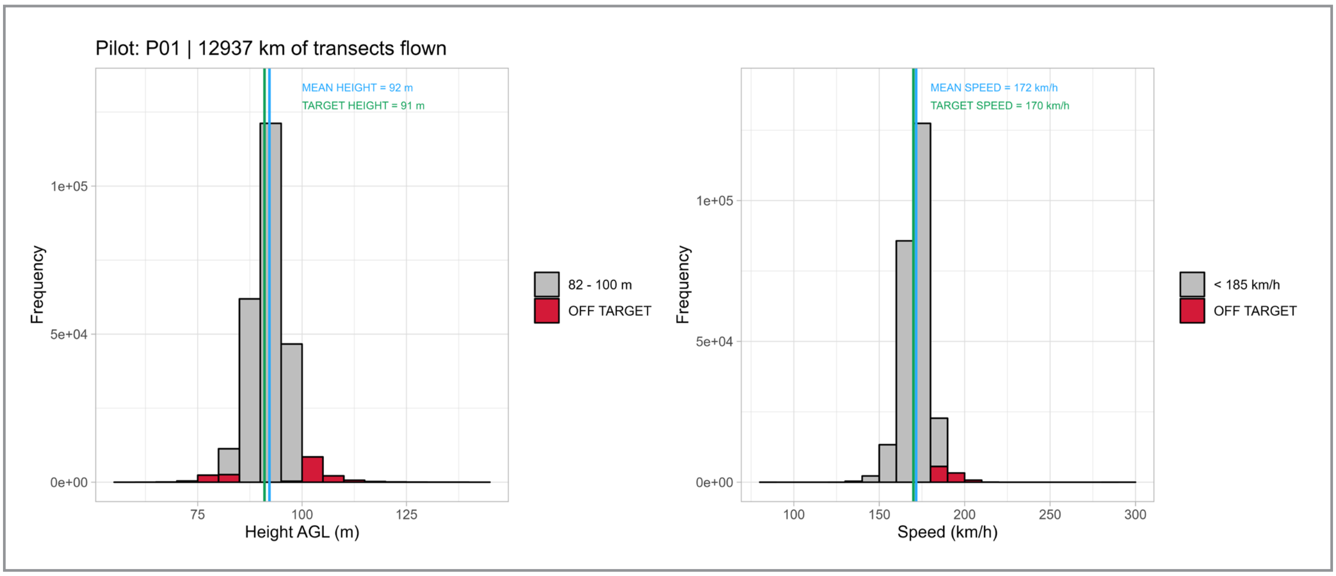


Figure 3.72: Histogram of Height AGL and flying speed for Pilot P01.

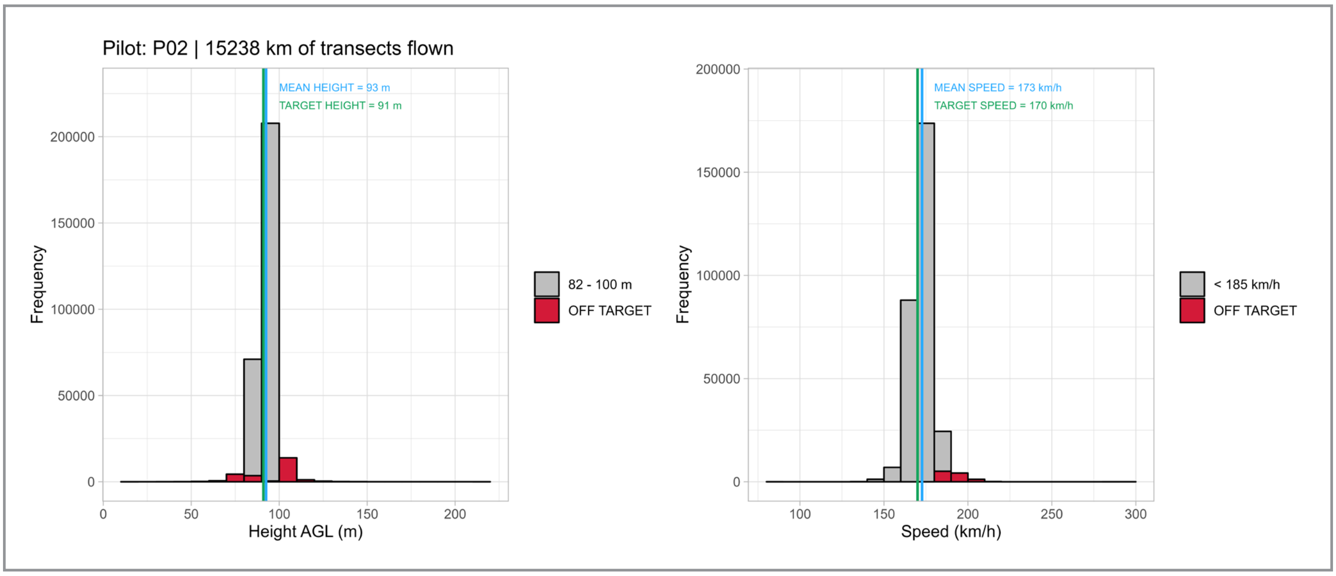


Figure 3.73: Histogram of Height AGL and flying speed for Pilot P02.

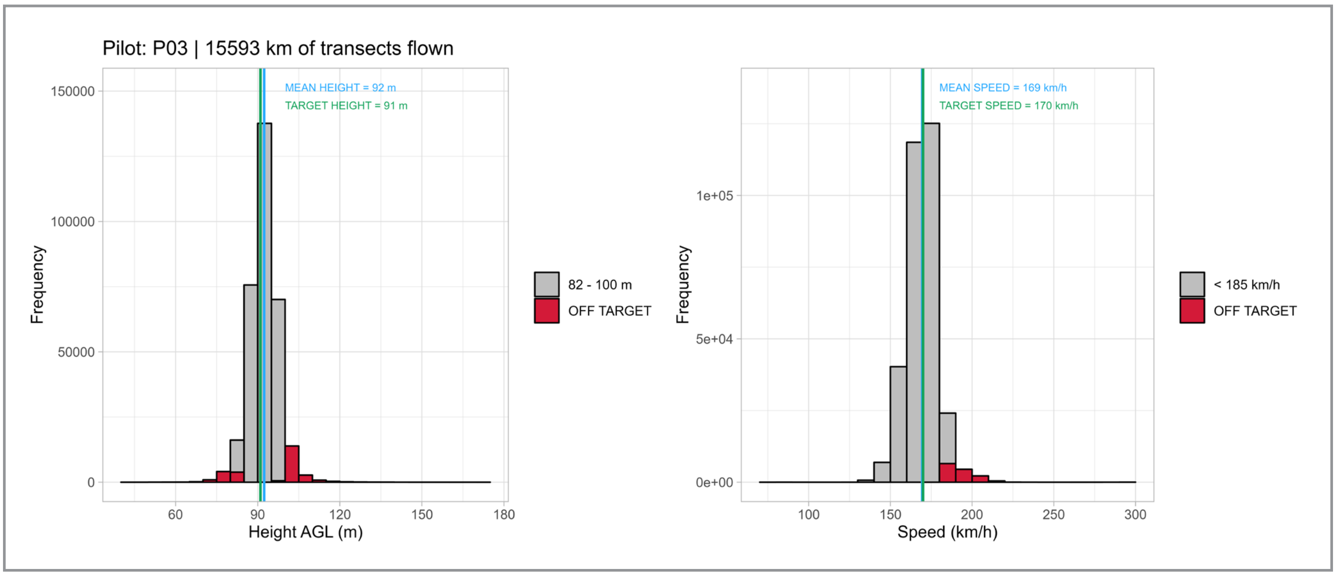


Figure 3.74: Histogram of Height AGL and flying speed for Pilot P03.

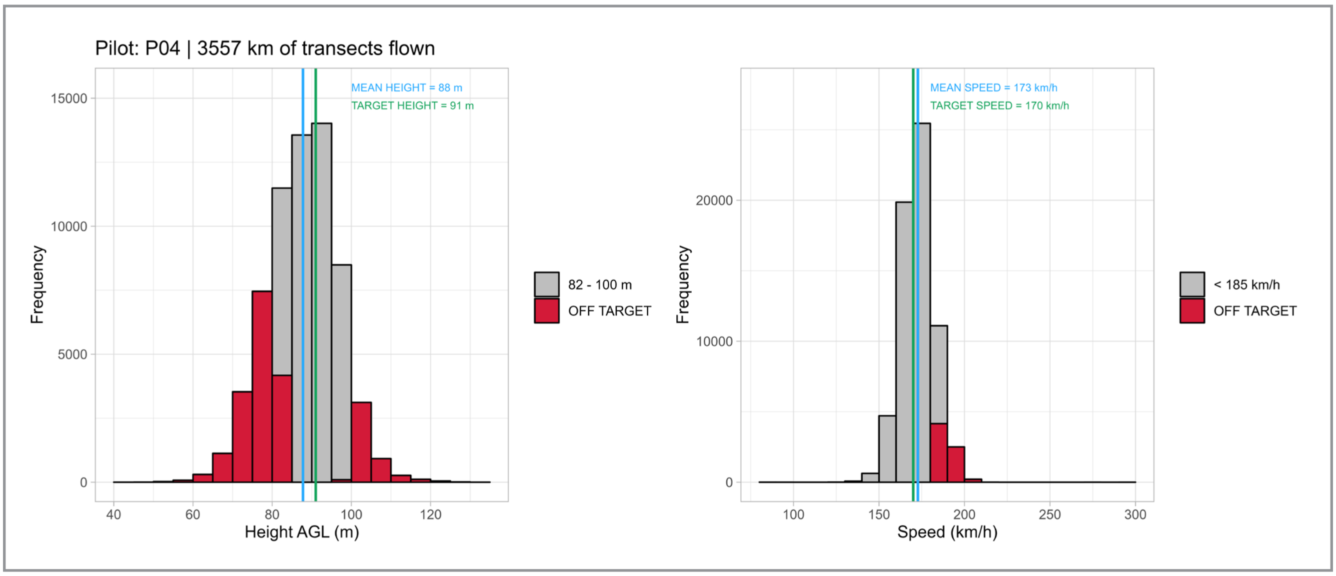


Figure 3.75: Histogram of Height AGL and flying speed for Pilot P04.

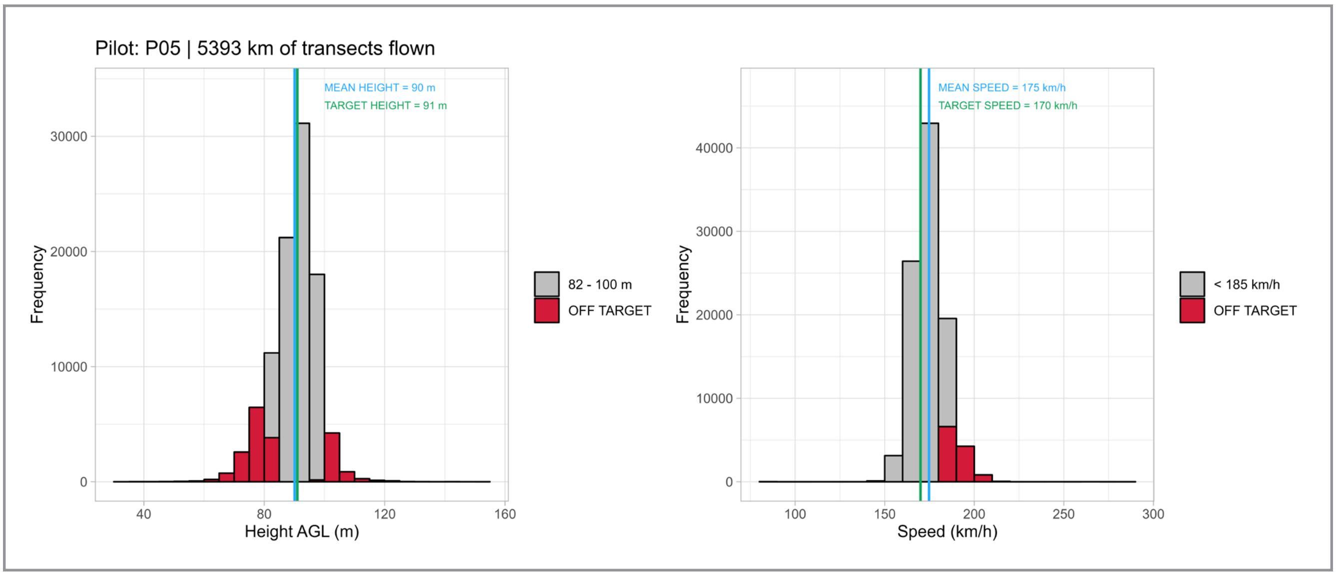


Figure 3.76: Histogram of Height AGL and flying speed for Pilot P05.

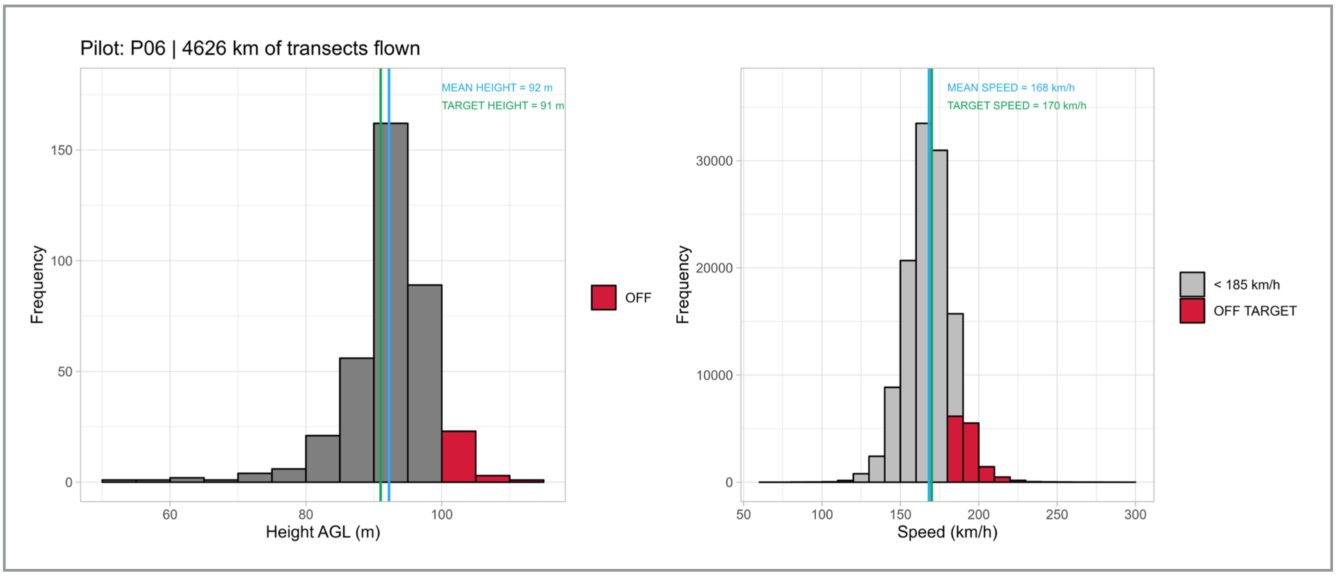


Figure 3.77: Histogram of Height AGL and flying speed for Pilot P06.

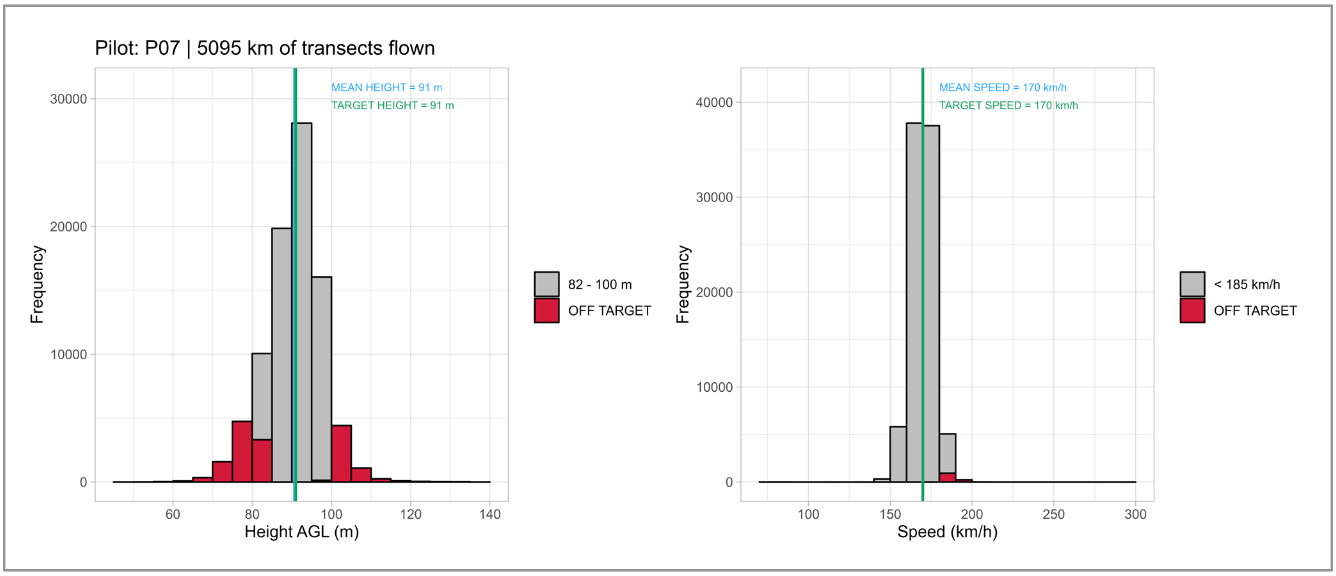


Figure 3.78: Histogram of Height AGL and flying speed for Pilot P07.

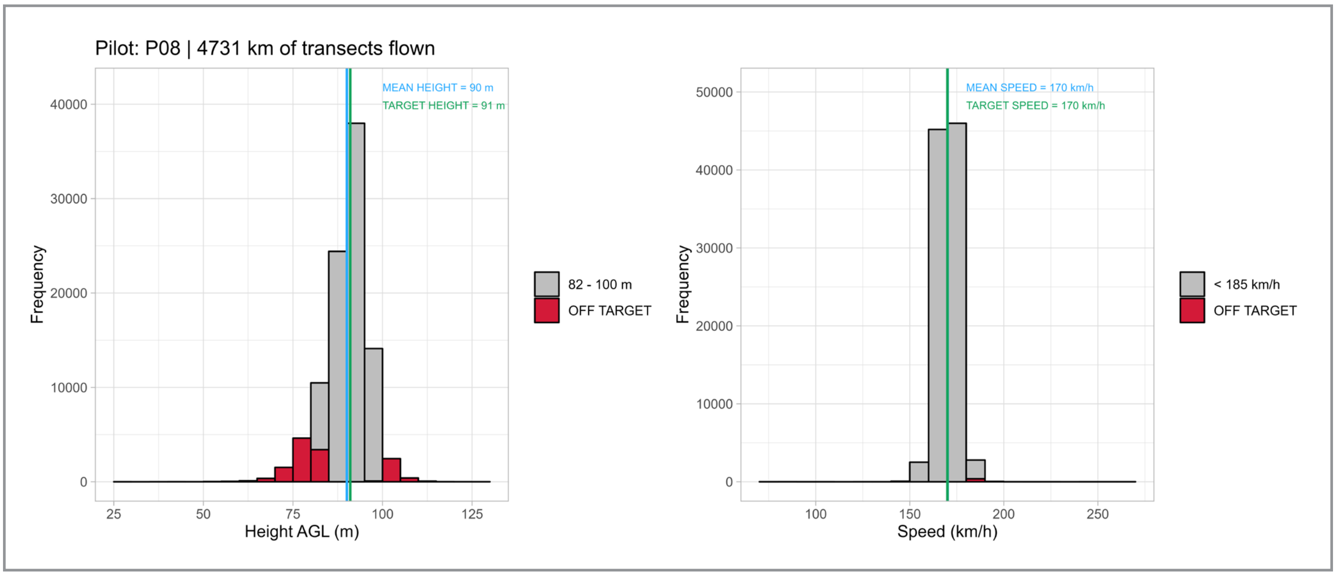


Figure 3.79: Histogram of Height AGL and flying speed for Pilot P08.

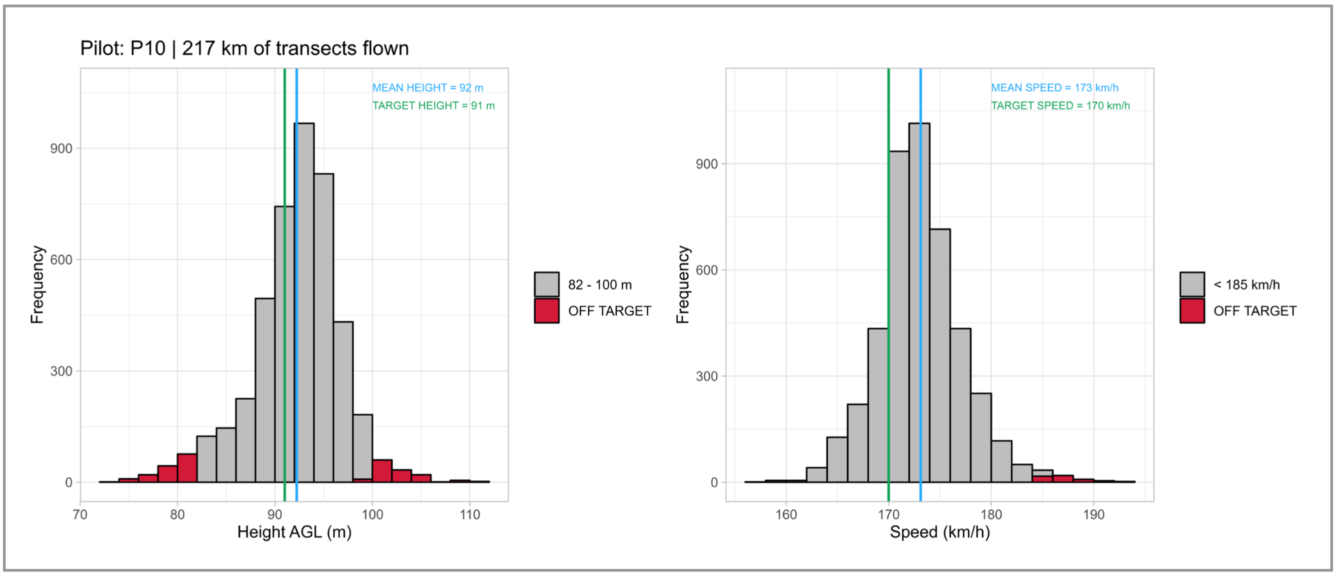


Figure 3.80: Histogram of Height AGL and flying speed for Pilot P10.

The results of the ANOVA of height and ground speed show statistical significance for all categorical variables as shown in Table 3.25.

Table 3.25: Results of the one-way ANOVA analyses performed on height and speed data, collected along transects. In the table df is degrees of freedom, and *** indicates a p-value <0.001, denoting statistical significance.

		df	Height	Speed
p	Pilot	7	***	***
a	Aircraft	4	***	***
f	Flight	167	***	***
st	Stratum	146	***	***

3.5.2 Observers

A total of nine teams collaborated to collect data on large herbivores, both wild and domestic, in 179 strata. In total, with the addition of the outcomes of the lechwe count and the reconnaissance flights, they made 19,466 observations inside the search strip, including 3,798 sightings of live elephants and 2,159 elephant carcasses. The corresponding number of individuals counted from those sightings was 132,806 individuals, of which 18% were live elephants, accounting for 24,493 individuals, while 1% were elephant carcasses, totalling 2,202. (See Table 3.26).

Table 3.26: Number of recorded sightings and counted individuals in the search strip during the survey, the red lechwe count and the three reconnaissance flights combined.

Area	Herbivore sightings	Live elephant sightings	Elephant carcass sightings	Herbivore individuals	Live elephants	Elephant carcasses
KAZA	19035	3708	2118	125820	23615	2157
LCW	263	1	0	5752	6	0
Recce	168	89	41	1234	872	45
Total	**19466**	**3798**	**2159**	**132806**	**24493**	**2202**

The results of the chi-square and Mann-Whitney U tests, to compare the number of observations and group size on the left and right side, are presented for all large herbivores, wild and domestic, and for each crew, in Table 3.28 to Table 3.35.

The difference between the announced and expected number of observations for each crew, taking into consideration the width of the respective search strip (Table 3.27), is presented in bar charts in Appendix 12. Additional information on the number of observations, minimum, maximum and mean group size, as well as standard deviation is provided for all species in Table 3.18.

Table 3.27: Percentages of the combined search strip width on either side of the aircraft.

Crew	% Left	% Right
C01	54.3	45.7
C02	51.0	49.0
C03	49.9	50.1
C04	49.9	50.1
C05	51.6	48.4
C06	46.5	53.5
C07	49.5	50.5
C08	48.6	51.4

Table 3.28: Results of the chi-square and Mann-Whitney U tests for crew C01.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Elephant										
all elephants	637	746.2	4372	6.9	738	628.8	4625	6.3	<0.001*	0.224
elephant bull	305	343.5	643	2.1	328	289.5	628	1.9	0.002*	
elephant family group	332	402.7	3729	11.2	410	339.3	3997	9.7	<0.001*	0.009*
all elephant carcasses	272	394.0	286	1.1	454	332.0	459	1.0	<0.001*	
C1-2 elephant carcasses	15	29.3	15	1.0	39	24.7	39	1.0	<0.001*	
C3-4 elephant carcasses	257	364.7	271	1.1	415	307.3	420	1.0	<0.001*	
elephant carcass one	6	10.9	6	1.0	14	9.1	14	1.0	0.029*	
elephant carcass two	9	18.5	9	1.0	25	15.5	25	1.0	0.001*	
elephant carcass three	139	191.0	147	1.1	213	161.0	218	1.0	<0.001*	
elephant carcass four	118	173.7	124	1.1	202	146.3	202	1.0	<0.001*	
Wildlife										
baboon	9	10.3	22	2.4	10	8.7	101	10.1	0.546	
buffalo	54	71.1	1556	28.8	77	59.9	1329	17.3	0.003*	0.003*
bushbuck	0	1.1	0	0.0	2	0.9	11	5.5	0.123	
bushpig	2	1.6	9	4.5	1	1.4	1	1.0	0.666	
duiker	23	39.6	24	1.0	50	33.4	58	1.2	<0.001*	
giraffe	45	63.5	105	2.3	72	53.5	162	2.2	<0.001*	
grysbok	1	0.5	1	1.0	0	0.5	0	0.0	0.359	
hippopotamus	32	46.7	232	7.2	54	39.3	219	4.1	0.001*	0.808
impala	73	109.1	906	12.4	128	91.9	1427	11.1	<0.001*	0.152
klipspringer	0	0.5	0	0.0	1	0.5	2	2.0	0.276	
kudu	33	57.5	95	2.9	73	48.5	225	3.1	<0.001*	
oryx	30	39.6	69	2.3	43	33.4	126	2.9	0.024*	
ostrich	26	44.5	43	1.7	56	37.5	102	1.8	<0.001*	
puku	0	0.5	0	0.0	1	0.5	4	4.0	0.276	
red lechwe	188	213.8	1897	10.1	206	180.2	2020	9.8	0.009*	0.770
reedbuck	4	16.8	13	3.2	27	14.2	53	2.0	<0.001*	
roan	19	33.1	62	3.3	42	27.9	122	2.9	<0.001*	0.637
sable	59	76.5	240	4.1	82	64.5	463	5.6	0.003*	0.015*
tsessebe	6	18.5	25	4.2	28	15.5	122	4.4	<0.001*	1.000
warthog	67	113.4	156	2.3	142	95.6	416	2.9	<0.001*	
waterbuck	2	6.5	9	4.5	10	5.5	52	5.2	0.009*	
wildebeest	46	49.4	482	10.5	45	41.6	455	10.1	0.476	0.481
zebra	108	146.0	1553	14.4	161	123.0	2137	13.3	<0.001*	0.062
Livestock										
cattle	211	236.6	3430	16.3	225	199.4	2976	13.2	0.014*	211
donkey	14	25.0	31	2.2	32	21.0	112	3.5	0.001*	14
horse	0	6.0	0	0.0	11	5.0	38	3.5	<0.001*	0
shoat	25	25.5	462	18.5	22	21.5	323	14.7	0.882	25

Table 3.29: Results of the chi-square and Mann-Whitney U tests for crew C02.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Elephant										
all elephants	525	502.4	3617	6.9	460	482.6	2676	5.8	0.149	
elephant bull	242	221.8	467	1.9	193	213.2	332	1.7	0.053	
elephant family group	283	280.5	3150	11.1	267	269.5	2344	8.8	0.831	0.080
all elephant carcasses	325	359.6	334	1.0	380	345.4	387	1.0	0.009*	
C1-2 elephant carcasses	7	5.1	7	1.0	3	4.9	3	1.0	0.229	
C3-4 elephant carcasses	318	354.4	327	1.0	377	340.6	384	1.0	0.006*	
elephant carcass one	2	2.0	2	1.0	2	2.0	2	1.0	0.968	
elephant carcass two	5	3.1	5	1.0	1	2.9	1	1.0	0.113	
elephant carcass three	42	55.1	46	1.1	66	52.9	69	1.0	0.012*	
elephant carcass four	276	299.4	281	1.0	311	287.6	315	1.0	0.054	
Wildlife										
baboon	20	19.9	186	9.3	19	19.1	113	5.9	0.972	0.068
buffalo	80	60.2	2326	29.1	38	57.8	519	13.7	<0.001*	0.014*
bushbuck	6	3.6	13	2.2	1	3.4	1	1.0	0.066	
bushpig	2	2.5	7	3.5	3	2.5	7	2.3	0.623	
duiker	110	118.3	125	1.1	122	113.7	140	1.1	0.275	
giraffe	140	104.6	332	2.4	65	100.4	117	1.8	<0.001*	
grysbok	0	0.5	0	0.0	1	0.5	6	6.0	0.308	
hippopotamus	80	64.8	253	3.2	47	62.2	186	4.0	0.007*	0.562
impala	194	171.4	1989	10.3	142	164.6	1286	9.1	0.013*	0.034*
klipspringer	1	0.5	2	2.0	0	0.5	0	0.0	0.327	
kudu	84	72.9	261	3.1	59	70.1	165	2.8	0.064	0.308
oryx	12	7.7	37	3.1	3	7.3	4	1.3	0.025*	
ostrich	49	42.8	118	2.4	35	41.2	65	1.9	0.179	
red lechwe	344	315.2	2512	7.3	274	302.8	1796	6.6	0.020*	0.336
reedbuck	18	17.3	37	2.1	16	16.7	27	1.7	0.821	
roan	26	18.9	99	3.8	11	18.1	19	1.7	0.019*	0.070
sable	70	52.0	299	4.3	32	50.0	151	4.7	<0.001*	0.677
sitatunga	8	6.1	8	1.0	4	5.9	5	1.2	0.278	
tsessebe	32	29.6	160	5.0	26	28.4	106	4.1	0.525	0.581
warthog	73	71.4	188	2.6	67	68.6	140	2.1	0.787	
waterbuck	12	12.8	57	4.8	13	12.2	70	5.4	0.764	0.639
wildebeest	28	30.1	118	4.2	31	28.9	142	4.6	0.586	0.695
zebra	133	109.1	864	6.5	81	104.9	590	7.3	0.001*	0.566
Livestock										
cattle	254	258.6	2521	9.9	253	248.4	2188	8.6	0.685	0.212
donkey	51	43.4	172	3.4	34	41.6	132	3.9	0.097	0.554
horse	13	13.3	44	3.4	13	12.7	38	2.9	0.919	0.524
shoat	46	36.2	886	19.3	25	34.8	293	11.7	0.020*	0.005*

Table 3.30: Results of the chi-square and Mann-Whitney U tests for crew C03.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Elephant										
all elephants	424	406.0	2470	5.8	388	406.0	2432	6.3	0.206	
elephant bull	189	179.5	318	1.7	170	179.5	312	1.8	0.316	
elephant family group	235	226.5	2152	9.2	218	226.5	2120	9.7	0.424	0.616
all elephant carcasses	125	178.5	125	1.0	232	178.5	237	1.0	<0.001*	
C1-2 elephant carcasses	0	1.5	0	0.0	3	1.5	3	1.0	0.083	
C3-4 elephant carcasses	125	177.0	125	1.0	229	177.0	234	1.0	<0.001*	
elephant carcass one	0	0.5	0	0.0	1	0.5	1	1.0	0.317	
elephant carcass two	0	1.0	0	0.0	2	1.0	2	1.0	0.157	
elephant carcass three	70	98.5	70	1.0	127	98.5	131	1.0	<0.001*	
elephant carcass four	55	78.5	55	1.0	102	78.5	103	1.0	<0.001*	
Wildlife										
baboon	1	2.5	6	6.0	4	2.5	18	4.5	0.18	
buffalo	39	36.4	529	13.6	34	36.6	446	13.1	0.546	0.942
bushbuck	0	0.5	0	0.0	1	0.5	2	2.0	0.318	
bushpig	1	2.0	1	1.0	3	2.0	8	2.7	0.317	
duiker	3	16.0	4	1.3	29	16.0	31	1.1	<0.001*	
giraffe	58	58.5	133	2.3	59	58.5	161	2.7	0.926	
hippopotamus	51	70.0	143	2.8	89	70.0	266	3.0	0.001*	
impala	35	56.0	453	12.9	77	56.0	811	10.5	<0.001*	0.105
kudu	19	33.0	53	2.8	47	33.0	139	3.0	<0.001*	
oryx	4	4.5	7	1.8	5	4.5	5	1.0	0.739	
ostrich	17	15.5	34	2.0	14	15.5	28	2.0	0.59	
red lechwe	179	242.5	1515	8.5	306	242.5	2518	8.2	<0.001*	0.74
reedbuck	23	25.0	40	1.7	27	25.0	56	2.1	0.572	
roan	2	5.5	12	6.0	9	5.5	36	4.0	0.035*	
sable	9	14.5	25	2.8	20	14.5	75	3.8	0.041*	
sitatunga	1	4.5	1	1.0	8	4.5	8	1.0	0.02*	
springbok	0	0.5	0	0.0	1	0.5	10	10.0	0.317	
tsessebe	10	12.0	33	3.3	14	12.0	76	5.4	0.414	0.1
warthog	25	40.5	69	2.8	56	40.5	146	2.6	<0.001*	
waterbuck	9	16.0	29	3.2	23	16.0	108	4.7	0.013*	0.523
wildebeest	3	5.0	12	4.0	7	5.0	99	14.1	0.206	
zebra	75	78.5	861	11.5	82	78.5	821	10.0	0.576	0.071
Livestock										
cattle	174	215.5	1722	9.9	257	215.5	3008	11.7	<0.001*	0.943
donkey	48	59.0	170	3.5	70	59.0	257	3.7	0.043*	0.832
horse	4	6.5	17	4.2	9	6.5	28	3.1	0.166	
shoat	15	27.0	248	16.5	39	27.0	742	19.0	0.001*	0.07

Table 3.31: Results of the chi-square and Mann-Whitney U tests for crew C04.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Elephant										
all elephants	143	156.0	778	5.4	169	156.0	1700	10.1	0.141	
elephant bull	62	57.5	102	1.6	53	57.5	102	1.9	0.401	
elephant family group	81	98.5	676	8.3	116	98.5	1598	13.8	0.013*	<0.001*
all elephant carcasses	81	101.5	82	1.0	122	101.5	123	1.0	0.004*	
C1-2 elephant carcasses	5	17.5	5	1.0	30	17.5	31	1.0	<0.001*	
C3-4 elephant carcasses	76	84.0	77	1.0	92	84.0	92	1.0	0.217	
elephant carcass one	2	2.0	2	1.0	2	2.0	2	1.0	1	
elephant carcass two	3	15.5	3	1.0	28	15.5	29	1.0	<0.001*	
elephant carcass three	24	33.0	25	1.0	42	33.0	42	1.0	0.027*	
elephant carcass four	52	51.0	52	1.0	50	51.0	50	1.0	0.843	
Wildlife										
baboon	1	2.0	1	1.0	3	2.0	71	23.7	0.317	
buffalo	41	38.5	649	15.8	36	38.5	789	21.9	0.569	0.747
bushbuck	0	1.5	0	0.0	3	1.5	3	1.0	0.083	
bushpig	0	1.0	0	0.0	2	1.0	6	3.0	0.157	
duiker	29	35.0	31	1.1	41	35.0	45	1.1	0.151	
giraffe	17	19.0	37	2.2	21	19.0	39	1.9	0.516	
grysbok	0	3.0	0	0.0	6	3.0	6	1.0	0.014*	
hippopotamus	23	25.0	72	3.1	27	25.0	112	4.1	0.572	0.217
impala	8	19.0	45	5.6	30	19.0	259	8.6	<0.001*	0.448
kudu	23	24.0	63	2.7	25	24.0	76	3.0	0.773	
oryx	3	2.0	16	5.3	1	2.0	1	1.0	0.317	
ostrich	10	11.5	21	2.1	13	11.5	19	1.5	0.532	
puku	0	3.5	0	0.0	7	3.5	28	4.0	0.008*	
red lechwe	55	66.0	696	12.7	77	66.0	693	9.0	0.056	0.212
reedbuck	5	8.5	11	2.2	12	8.5	33	2.8	0.09	
roan	6	7.0	6	1.0	8	7.0	20	2.5	0.593	
sable	36	42.0	255	7.1	48	42.0	335	7.0	0.19	0.022*
sitatunga	1	1.0	1	1.0	1	1.0	1	1.0	1	
springbok	1	0.5	2	2.0	0	0.5	0	0.0	0.317	
tsessebe	2	2.0	19	9.5	2	2.0	24	12.0	1	
warthog	25	36.0	76	3.0	47	36.0	161	3.4	0.01*	
waterbuck	0	3.5	0	0.0	7	3.5	34	4.9	0.008*	
wildebeest	7	12.0	58	8.3	17	12.0	175	10.3	0.041*	0.588
zebra	23	29.0	100	4.3	35	29.0	305	8.7	0.115	0.002*
Livestock										
cattle	54	67.0	624	11.6	80	67.0	1475	18.4	0.025*	0.178
donkey	4	5.0	15	3.8	6	5.0	16	2.7	0.527	
horse	0	2.0	0	0.0	4	2.0	26	6.5	0.046*	
shoat	3	5.0	71	23.7	7	5.0	93	13.3	0.206	

Table 3.32: Results of the chi-square and Mann-Whitney U tests for crew C05.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Elephant										
all elephants	26	23.9	136	5.2	20	22.1	108	5.4	0.539	
elephant bull	10	9.4	10	1.0	8	8.6	11	1.4	0.763	
elephant family group	16	14.6	126	7.9	12	13.4	97	8.1	0.586	1
all elephant carcasses	5	5.7	5	1.0	6	5.3	6	1.0	0.664	
C1-2 elephant carcasses	0	0.5	0	0.0	1	0.5	1	1.0	0.298	
C3-4 elephant carcasses	5	5.2	5	1.0	5	4.8	5	1.0	0.899	
elephant carcass two	0	0.5	0	0.0	1	0.5	1	1.0	0.298	
elephant carcass three	5	5.2	5	1.0	5	4.8	5	1.0	0.899	
Wildlife										
buffalo	8	4.7	68	8.5	1	4.3	50	50.0	0.027*	
bushbuck	0	3.1	0	0.0	6	2.9	7	1.2	0.011*	
bushpig	5	7.3	14	2.8	9	6.7	21	2.3	0.223	
duiker	34	30.2	36	1.1	24	27.8	25	1.0	0.313	
grysbok	1	0.5	1	1.0	0	0.5	0	0.0	0.337	
hartebeest	48	46.3	393	8.2	41	42.7	284	6.9	0.715	0.342
hippopotamus	22	16.6	120	5.5	10	15.4	38	3.8	0.058	0.133
impala	35	35.4	367	10.5	33	32.6	237	7.2	0.93	0.67
kudu	6	12.5	19	3.2	18	11.5	53	2.9	0.008*	0.428
puku	33	34.3	321	9.7	33	31.7	157	4.8	0.745	<0.001*
red lechwe	127	136.2	2809	22.1	135	125.8	2939	21.8	0.253	0.437
reedbuck	6	8.8	11	1.8	11	8.2	22	2.0	0.168	
roan	9	10.4	100	11.1	11	9.6	80	7.3	0.531	0.307
sable	63	75.9	486	7.7	83	70.1	510	6.1	0.032*	0.169
sitatunga	0	0.5	0	0.0	1	0.5	1	1.0	0.298	
warthog	65	67.6	263	4.0	65	62.4	231	3.6	0.648	0.331
waterbuck	18	17.2	86	4.8	15	15.8	59	3.9	0.77	0.912
wildebeest	8	7.8	64	8.0	7	7.2	30	4.3	0.918	0.435
zebra	10	8.8	51	5.1	7	8.2	39	5.6	0.573	0.767
Livestock										
cattle	139	153.4	1616	11.6	156	141.6	1701	10.9	0.093	0.959
donkey	1	3.1	2	2.0	5	2.9	12	2.4	0.083	
shoat	40	43.2	442	11.1	43	39.8	561	13.0	0.488	0.826

Table 3.33: Results of the chi-square and Mann-Whitney U tests for crew C06.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Wildlife										
bushbuck	0	0.5	0	0.0	1	0.5	1	1.0	0.356	
bushpig	0	0.5	0	0.0	1	0.5	1	1.0	0.356	
duiker	14	8.3	14	1.0	4	9.7	4	1.0	0.007*	
giraffe	1	1.8	12	12.0	3	2.2	5	1.7	0.399	
kudu	0	0.9	0	0.0	2	1.1	10	5.0	0.192	
roan	1	0.9	1	1.0	1	1.1	1	1.0	0.91	
sable	3	3.2	3	1.0	4	3.8	49	12.2	0.867	
tsessebe	0	0.5	0	0.0	1	0.5	1	1.0	0.356	
warthog	2	1.4	4	2.0	1	1.6	1	1.0	0.473	
wildebeest	2	0.9	9	4.5	0	1.1	0	0.0	0.125	
Livestock										
cattle	12	8.7	155	12.9	7	10.3	100	14.3	0.133	0.497
shoat	1	1.4	4	4.0	2	1.6	21	10.5	0.66	

Table 3.34: Results of the chi-square and Mann-Whitney U tests for crew C07.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Elephant										
all elephants	20	15.2	101	5.0	11	15.8	46	4.2	0.084	
elephant bull	8	5.4	12	1.5	3	5.6	3	1.0	0.115	
elephant family group	12	9.8	89	7.4	8	10.2	43	5.4	0.325	0.332
all elephant carcasses	2	1.0	2	1.0	0	1.0	0	0.0	0.149	
C3-4 elephant carcasses	2	1.0	2	1.0	0	1.0	0	0.0	0.149	
elephant carcass three	1	0.5	1	1.0	0	0.5	0	0.0	0.308	
elephant carcass four	1	0.5	1	1.0	0	0.5	0	0.0	0.308	
Wildlife										
buffalo	10	7.3	198	19.8	5	7.7	54	10.8	0.171	
bushbuck	14	6.9	21	1.5	0	7.1	0	0.0	<0.001*	
bushpig	4	3.4	22	5.5	3	3.6	3	1.0	0.666	
duiker	195	176.4	221	1.1	165	183.6	187	1.1	0.05*	
giraffe	6	4.9	18	3.0	4	5.1	7	1.8	0.487	
hartebeest	36	34.3	192	5.3	34	35.7	183	5.4	0.684	0.725
hippopotamus	14	13.7	124	8.9	14	14.3	94	6.7	0.916	0.695
impala	48	46.1	402	8.4	46	47.9	456	9.9	0.689	0.773
kudu	18	14.7	93	5.2	12	15.3	51	4.2	0.228	0.415
oribi	3	1.5	7	2.3	0	1.5	0	0.0	0.077	
puku	77	53.4	632	8.2	32	55.6	268	8.4	<0.001*	0.854
red lechwe	27	26.5	585	21.7	27	27.5	421	15.6	0.883	0.176
reedbuck	14	8.8	38	2.7	4	9.2	7	1.8	0.015*	
roan	21	14.7	80	3.8	9	15.3	41	4.6	0.021*	0.981
sable	44	51.9	218	5.0	62	54.1	336	5.4	0.123	0.632
sitatunga	1	1.0	1	1.0	1	1.0	2	2.0	0.977	
warthog	88	82.3	299	3.4	80	85.7	328	4.1	0.381	0.217
waterbuck	27	17.6	113	4.2	9	18.4	19	2.1	0.002*	0.104
wildebeest	17	11.8	83	4.9	7	12.2	80	11.4	0.032*	0.92
zebra	11	6.9	56	5.1	3	7.1	11	3.7	0.027*	
Livestock										
cattle	133	133.3	1348	10.1	139	138.7	1039	7.5	0.973	0.071
donkey	3	1.5	8	2.7	0	1.5	0	0.0	0.077	
shoat	22	24.0	352	16.0	27	25.0	332	12.3	0.566	0.344

Table 3.35: Results of the chi-square and Mann-Whitney U tests for crew C08.

Each column shows the number of observations (O) compared to the expected number (E) given the percentage of the combined search strip width on each side of the aircraft, the number of individuals observed (I) and the average group size (MG).

	Left Side				Right Side				p value	
Species	O	E	I	MG	O	E	I	MG	Chi2	U
Elephant										
all elephants	63	56.4	254	4.0	52	58.6	240	4.6	0.215	
elephant bull	17	18.1	23	1.4	20	18.9	43	2.1	0.71	
elephant family group	46	38.2	231	5.0	32	39.8	197	6.2	0.078	0.286
all elephant carcasses	68	53.4	68	1.0	41	55.6	41	1.0	0.005*	
C3-4 elephant carcasses	68	53.4	68	1.0	41	55.6	41	1.0	0.005*	
elephant carcass three	18	9.8	18	1.0	2	10.2	2	1.0	<0.001*	
elephant carcass four	50	43.6	50	1.0	39	45.4	39	1.0	0.175	
Wildlife										
baboon	3	4.4	10	3.3	6	4.6	24	4.0	0.347	
buffalo	7	11.8	161	23.0	17	12.2	233	13.7	0.052	0.503
bushbuck	4	4.9	4	1.0	6	5.1	9	1.5	0.569	
duiker	0	2.0	0	0.0	4	2.0	5	1.2	0.05*	
hippopotamus	10	11.3	59	5.9	13	11.7	74	5.7	0.596	0.95
impala	98	80.4	1661	16.9	66	83.6	872	13.2	0.006*	0.133
kudu	12	7.3	17	1.4	3	7.7	5	1.7	0.016*	
sable	1	1.0	1	1.0	1	1.0	1	1.0	0.977	
warthog	9	7.3	25	2.8	6	7.7	24	4.0	0.394	
waterbuck	9	5.9	34	3.8	3	6.1	19	6.3	0.072	
zebra	13	15.7	52	4.0	19	16.3	70	3.7	0.343	0.422
Livestock										
cattle	303	283.7	2154	7.1	276	295.3	2025	7.3	0.109	0.323
donkey	22	26.5	78	3.5	32	27.5	75	2.3	0.225	0.05
shoat	184	188.7	1804	9.8	201	196.3	1861	9.3	0.635	0.802

3.5.3 Photo interpretation

The survey standards mandate photographic documentation for all observed groups with more than 9 individuals, and for all elephant carcasses. Out of the 19,298 observations of large wild and domestic herbivores made in the search strips, 5,910 observations (30.6%) met these criteria for photo verification. The primary purpose of matching these observations with photographs was to confirm the estimated group size or identify the category of the elephant carcass, or in certain cases, both. Similarly, among the 5,826 observations of elephants (both live and carcasses) made in the search strips, 2,878 observations (49.4%) required photo matching to comply with the survey standards.

A total of 3,422 usable photographs, meeting quality criteria such as being in focus, well-framed, with the subject unobscured by vegetation, were added to the database. 3,326 of these photographs (97.2%) were successfully matched to specific observations. Among the matched photographs, 2,111 observations (63.4%) required photo verification, while for 1,113 observations (33.4%), photo matching was optional. Additionally, the remaining 102 photographs captured sightings that the observers had missed and included 23 different species, including elephants.

It was found that only 36% (2,111 out of 5,910) of the observations requiring photo verification were effectively matched to a useable photograph. Among the 2,111 photographs that were matched to observations requiring photo support, 98 (4.6%) led to a correction of the species identification or carcass age category, 728 (34.5%) led to a correction of the estimated group size, and 6 (<0.1%) photos resulted in corrections in both aspects.

Corrections on identification only concerned the elephant carcass age categories and the following species: cattle and buffalo, shoat and impala, elephant bull and elephant family groups. Corrections made to the group size estimates were both downward and upward, as the scatter plot in Fig. 3.81 illustrates. For each image it is first necessary to answer the question: does this photo provide insights that would improve the information given by the observer: is it in focus, taken at the right time and in the right position? Are species visible and not covered by thick vegetation? If the answer is no, then the information provided by the photo is not retained in favour of that provided by the observer, as the second scatter plot in Fig. 3.81 illustrates.

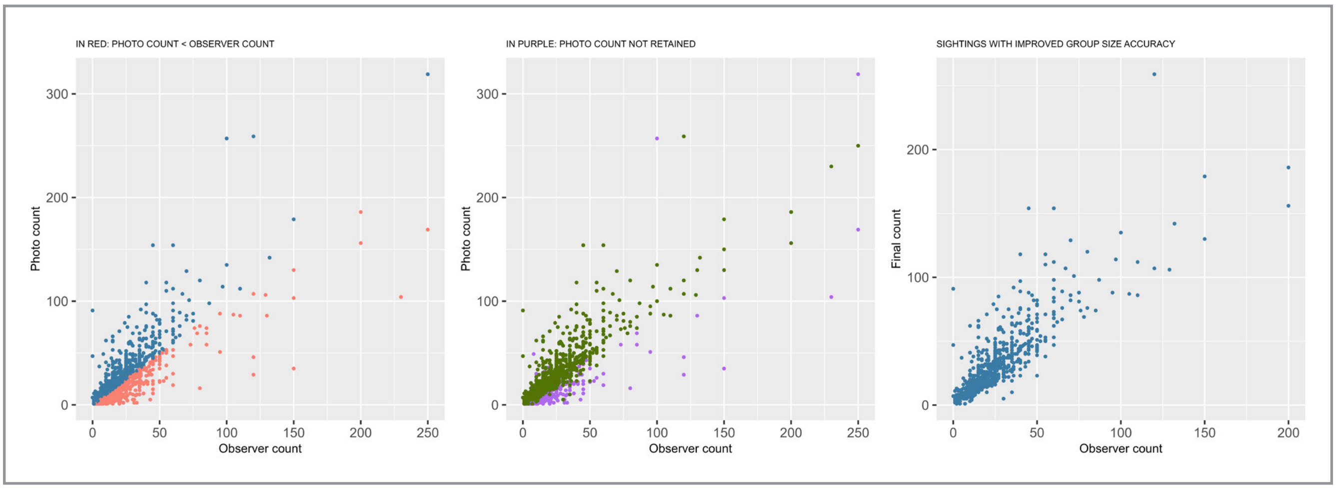


Figure 3.81: Scatterplots providing insights into the photo interpretation process. All dots represent an observation with a matched photograph. Left: photo counts inferior to observer count are shown in red. Middle: Ignored photo counts are shown in purple. Right: Observations with an improved group size estimate are shown in blue.

The amplitude of the correction varies with group size and Fig. 3.82 shows three bar charts that evaluate for different group sizes, the total and average number of individuals added, as well as the number of individuals added as a percentage of the group size.

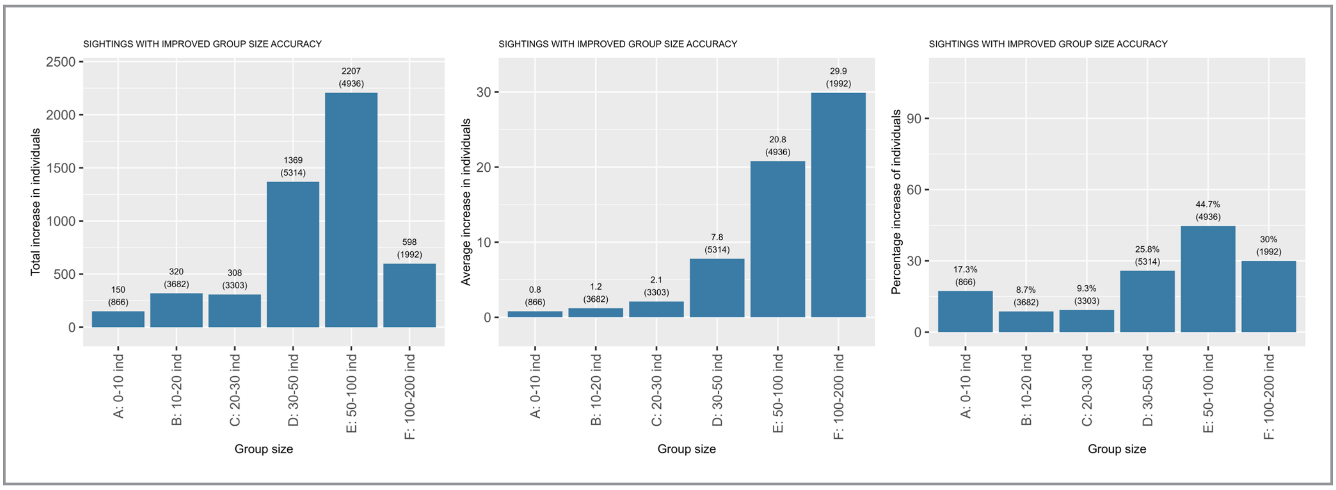


Figure 3.82: Net direction and magnitude of the corrections made to group size estimates. Left: total difference in the number of individuals in each herd size category. Middle: average difference in the number of individuals per sighting in each herd size category. Right: difference in the number of individuals in each herd size category as a percentage of the original number of individuals in this category.

In relation to elephant observations, 42.5% of instances necessitating photographic verification were matched. Of these observations requiring photographic interpretation, 26.4% comprised elephant carcasses requiring confirmation of the age category estimate. Consequently, the accuracy of the information collected for 8.4% of the elephant observations (live and carcasses) that required verification, was improved through the photo interpretation process. The net direction and magnitude of the corrections made to the elephant herd size estimates are given in the bar graphs in Fig. 3.83

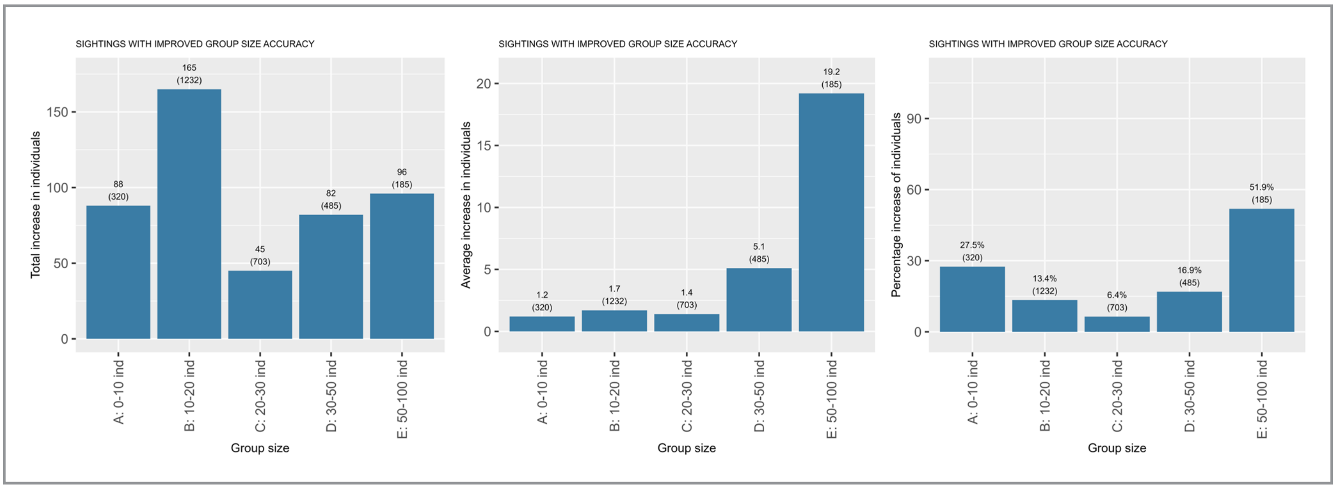


Figure 3.83: Net direction and magnitude of the corrections made to elephant herd size estimates. Left: total difference in the number of individuals in each herd size category. Middle: average difference in the number of individuals per sighting in each herd size category. Right: difference in the number of individuals in each herd size category as a percentage of the original number of individuals in this category.

The corrections made during the photo interpretation process were reflected in the final population estimates. Table 3.36 shows the different results of the analyses for elephants, with and without these corrections.

Table 3.36: Impact of the photo interpretation process on the final population estimates for the KAZA TFCA.

	Observer Data		Final Data		Difference (%)
	Estimate	CI	Estimate	CI	
all elephants	222992	±16362	227900	±16743	+2.2
elephant bull	32547	±2882	32559	±2789	0.0
elephant family group	190445	±15822	195342	±16180	+2.6
all elephant carcasses	26321	±1634	26641	±1645	+1.2
C1-2 elephant carcasses	1494	±333	1165	±290	-22.0
C3-4 elephant carcasses	24826	±1572	25476	±1595	+2.6
elephant carcass one	290	±121	277	±115	-4.5
elephant carcass two	1204	±311	888	±266	-26.2
elephant carcass three	9468	±998	9753	±998	+3.0
elephant carcass four	15358	±1137	15722	±1148	+2.4

4 DISCUSSION

4. Discussion

The primary objective of this survey was to provide a relatively accurate and precise numeric estimate for the elephant population in the KAZA TFCA. It has previously been difficult to do so due to uncertainty resulting from substantial transboundary movements and a lack of synchronisation and standardisation between in-country assessments. In this section we discuss the elephant population and carcass estimates as well as their implications at the KAZA TFCA scale. A brief comparison of the estimates with previous surveys at the relevant country and or superstratum level is provided. In addition, we evaluate the validity of the results in terms of the survey design and execution and provide recommendations for future surveys.

It is important to note that the survey was designed to provide accurate and precise results for elephants at the KAZA TFCA scale, and serves as a baseline for future population assessments, rather than for smaller land units, particularly at the stratum level. As the survey was specifically designed to focus on elephants, it is also important to note that estimates for non-elephant species cannot be considered as KAZA-wide estimates. The survey did not have a defined survey zone specifically tailored for these other species, which means that the estimates only represent the surveyed area within the KAZA TFCA and should not be extrapolated to the entire KAZA-wide region. Furthermore, considering the landscape heterogeneity across the extensive KAZA TFCA region, detection probability is bound to vary with vegetation thickness, and this should be given careful consideration when interpreting the survey results.

4.1 Population Estimates

4.1.1 Elephant population

The 2022 dry season survey estimated there to be 227900 (±16743) elephants in the KAZA TFCA survey area. This estimate has a high level of relative precision (7% PRP) indicative of a well-designed survey. Additionally, 872 elephants were counted on reconnaissance flights, including a noteworthy observation of, 552 elephants counted north of Sioma, where 508 individuals were found in a single herd.

Across the KAZA TFCA, 58% of the elephants were found to be in Botswana, 29% in Zimbabwe, 9% in Namibia, and the remaining 4% were found in Zambia and Angola combined. The distribution and density of elephants during the survey period illustrated in Fig. 3.1 and Fig. 3.2 confirms the ecologically anticipated pattern of higher density and aggregation near permanent water sources like the Okavango and Chobe-Linyanti-Kwando River systems, as well as in parts of north-western Matabeleland, where artificial water supplies are widely available in Hwange National Park. Conversely, the density of elephants is lower in regions with less water.

Figure 3.58 displays the distribution of elephants in relation to cattle and human settlements, revealing a pattern of spatial segregation between elephants and the presence of humans and livestock. The general trend of elephants being absent from regions that are heavily populated by humans and livestock is apparent.

To provide a comparative sense of our understanding of the elephant population in the KAZA TFCA since 2014, a summary of results from recent elephant surveys conducted in the region is provided (Tables 4.1 and 4.2). Caution should be applied when comparing the estimates from different surveys due to the variability in timing, area covered, precision and methodologies used. Despite these limitations, the historical survey data provides useful insights into national level elephant populations in the region and can inform conservation efforts.

Table 4.1: Comparison of elephant estimates from this survey with those from surveys that were incorporated into the 2016 African elephant Status Report (Thouless, et al., 2016), i.e., from the Great Elephant Census and Namibia.

Zone	KAZA Elephant Survey 2022						2016 AESR							
	Pop^n Estimate	95% Confidence Range			PRP	Area (km^2)	Pop^n Estimate	95% Confidence Range			PRP	Area (km^2)	Survey Year	Source
		Lower CL		Upper CL				Lower CL		Upper CL				
KAZA	227900	211157	-	244643	7%	310865								
Angola	5983	355	-	12444	108%	36343	3395	1778	-	5012	48%	41542	2015	Chase & Schlossberg, 2016
Botswana	131909	120078	-	143740	9%	123666	129939	117426	-	142453	10%	98425	2014	Chase et al., 2015
Namibia	21090	17225	-	24955	18%	36362								
Kavango Zambezi	12345	9863	-	14827	20%	18059	13136	9703	-	16529	26%	17474	2015	Gibson & Craig, 2015a
Khaudum Nyae Nyae	8745	5736	-	11754	34%	18303	6413	3847	-	8979	40%	12851	2015	Gibson & Craig, 2015b
Zambia	3840	2442	-	5238	36%	73830								
Kafue	3840	2442	-	5238	36%	63879	6688	3945	-	9432	41%	45030	2015	DNPW, 2016
Sioma	552*					9951	48	0	-	126	131%	4482	2015	DNPW, 2016
Zimbabwe	65028	55571	-	74485	15%	40665								
North-west Matabeleland	61531	52123	-	70939	15%	25045	53991	46280	-	61702	14%	24959	2014	Dunham et al., 2015a
Sebungwe	3498	2478	-	4518	29%	15619	3407	2192	-	4622	36%	15527	2014	Dunham et al., 2015b

* Number counted during a reconnaissance flight, of which 508 were counted from photographs in a single herd.

Table 4.2: Comparison of elephant estimates from this survey with those from surveys conducted subsequently to the data presented in the Table 4.1 above.

Zone	KAZA Elephant Survey 2022						Most recent prior surveys							
	Pop^n Estimate	95% Confidence Range			PRP	Area (km^2)	Pop^n Estimate	95% Confidence Range			PRP	Area (km^2)	Survey Year	Source
		Lower CL		Upper CL				Lower CL		Upper CL				
KAZA	227900	211157	-	244643	7%	310865								
Botswana	131909	119976	-	143842	9%	123666	126114	116191	-	136037	8%	103662	2018	Chase et al., 2018
Namibia	21090	17202	-	24978	18%	36362								
Kavango Zambezi	12345	9826	-	14864	20%	18059	12008	9410	-	14606	22%	17380	2019	Craig & Gibson, 2019a
Khaudum Nyae Nyae	8745	5736	-	11754	34%	18303	7999	4970	-	11028	38%	14029	2019	Craig & Gibson, 2019b
Zambia	3840	2442	-	5238	36%	73830								
Kafue	3840	2442	-	5238	36%	63879	5603	1982	-	9224	65%	64139	2021	DNPW, 2021
Kafue	3840	2442	-	5238	36%	63879	4606	1216	-	7996	74%	58331	2019	DNPW, 2019
Sioma	552 *					9951	285 **					9970	2019	DNPW, 2019

* Number counted during a reconnaissance flight, of which 508 were counted from photographs in a single herd.
** Number counted during a recconaissance flight of which 232 were in a single herd.

4.1.2 Elephant carcasses

The KAZA TFCA survey area has an all-carcass ratio (CR14) of 10.47%, calculated from the 26641 (±1645) elephant carcasses estimated. Douglas-Hamilton and Burrill (1991) showed that such carcass ratios above 8% may be indicative of high mortality and warrant special attention. Given the absence of previously estimated carcass ratios at the KAZA TFCA level, the value calculated from this survey serves as a useful baseline value and potentially as a cautionary signal of a possible negative population trend. This will however require further assessment to confirm.

Notably among the various zones, Sebungwe (17.46%), Angola (16.27%) and Botswana (12.80%) had the highest all-carcass ratios, while other zones had all-carcass ratios that were below 8% (Table 3.5). Comparing the current carcass ratios with those from spatially localised previous surveys (Tables 4.3 and 4.4 below), the CR14 for the identified zones has decreased for all zones, except for Botswana. The underlying reasons for high mortality rates could be diverse and are likely to be a combination of several factors such as of poaching, habitat loss (i.e., elephant population compression) and associated human-elephant conflict, disease, and other natural causes. For the conservation of elephants, a priority is to carry out further investigations to identify the drivers of the high mortality rates and to ensure that appropriate interventions are implemented.

Table 4.3: Comparison of elephant carcass ratios from this survey with those from surveys that were incorporated into the 2016 African elephant Status Report (Thouless, et al., 2016), i.e., from the Great Elephant Census and Namibia.

Zone	KAZA Elephant Survey 2022		2016 AESR			
	CR14	CR12	CR14	CR12	Survey Year	Source
KAZA	10,47%	0,51%				
Angola	16,27%	0,57%	30,00%	10,40%	2015	Chase & Schlossberg, 2016
Botswana	12,80%	0,72%	6,90%	0,09%	2014	Chase et al., 2015
Namibia	3,57%	0,43%				
Kavango Zambezi	4,60%	0,49%	8,27%	1,50%	2015	Gibson & Craig, 2015a
Khaudum Nyae-Nyae	2,07%	0,36%	0,25%	0%	2015	Gibson & Craig, 2015b
Zambia	3,44%	0,26%				
Kafue	3,25%	0,26%	7,02%	0,13%	2015	DNPW, 2016
Sioma*	100%	0,00%	85,28%	14,28%	2015	DNPW, 2016
Zimbabwe	7,36%	0,10%				
North-West Matabeleland	6,71%	0,10%	7,00%	0,35%	2014	Dunham et al., 2015a
Sebungwe	17,46%	0,00%	30,20%	2,17%	2014	Dunham et al., 2015b

* Refer to the discussion below

Table 4.4: Comparison of elephant carcass ratios from this survey with those from surveys conducted subsequently to the data presented in the Table 4.3 above.

Zone	KAZA Elephant Survey 2022		Most recent prior surveys			
	CR14	CR12	CR14	CR12	Survey Year	Source
KAZA	10,47%	0,51%				
Botswana	12,80%	0,72%	8,10%	0,70%	2018	Chase et al., 2018
Namibia	3,57%	0,43%				
Kavango Zambezi	4,60%	0,49%	NA	NA	2019	Craig & Gibson, 2019a
Khaudum Nyae-Nyae	2,07%	0,36%	1,70%	0,25%	2019	Craig & Gibson, 2019b
Zambia	3,44%	0,26%				
Kafue	3,25%	0,26%	3,00%	0%	2021	DNPW, 2021
Kafue	3,25%	0,26%	9,00%	3,70%	2019	DNPW, 2019
Sioma*	100%	0,00%	5,00%	2,70%	2019	DNPW, 2019

* Refer to the discussion below

The Sioma carcass ratio of 100%, reflects the absence of live elephants being observed during the sample count, while eight carcasses were recorded. Very high carcass ratios are common in seasonal elephant habitats due to carcass accumulation during elephant occupancy, and subsequent emigration of elephants by the time of the survey. This pattern is typical of Sioma Ngwezi National Park as seen in former survey reports and is further reflected in the stratum-level carcass ratios shown in Fig. 3.9. The seasonal movement of elephants means carcass ratios alone may not be sufficient to assess population health at the stratum level. To identify areas with high mortality at fine geographical scales, the carcass ratio has been filtered for strata where elephants were present (>30 individuals seen in the sample), producing the map in Fig. 3.11.

The notable increase in carcass numbers observed in Botswana, particularly in carcass categories 3 and 4, compared to previous surveys, presents a challenge in interpretation. This phenomenon is likely a result of several factors. First, there might have been an actual increase in mortality rates in the past. Second, there may be improved detection of carcasses due to the implementation of a narrower search strip compared to previous surveys. Additionally, the broader survey coverage, particularly in predominantly wet-season habitats, would have contributed to additional carcasses observed.

To gain a comprehensive understanding of the underlying causes for this phenomenon, a more in-depth analysis is required. Further investigation should focus on examining the individual and combined impacts of these factors on the observed increase in carcass numbers.

The fresh and recent carcass ratio (CR12) serves as an index of recent mortality, since these carcass categories represent elephants that have died in the 12 months prior to the survey. There were an estimated 1165 (±290) fresh and recent elephant carcasses in the KAZA TFCA survey area, resulting in a CR12 of 0.51%. The highest CR12 ratios were observed in Botswana (0.72%), Angola (0.57%), and the Kavango Zambezi zone (0.49%) (refer to Table 3.5). No specific threshold value for this ratio has been identified as defining excessive mortality (i.e., mortality rates indicating a declining population), and these results offer a relative measure of recent deaths and can serve as a benchmark for future comparisons. From the tables presented above, the recent mortality rates appear to be similar to past surveys or have decreased across the various zones, countering the suggested declining populations derived from the interpretation of the CR14 ratios. Of concern is the observation that in Botswana the CR12 increased from 0.1% in 2014 to 0.70% in 2018 and remains at a similar level at 0.72% in 2022.

By examining the spatial distribution and density of category 1 and 2 carcasses (refer to Fig. 3.5 & Fig. 3.6) and using the CR12 choropleth map (refer to Fig. 3.12), it is possible to pinpoint areas with the highest recent mortality. Generally, there is a concentration of fresh and recent carcasses in the border region between Botswana and Namibia along the Kwando-Linyanti-Chobe River system. The strata with the highest CR12 values were identified as CH1 and SAVN (Savuti north), with an estimated 249 (±110) and 266 (±129) fresh and recent carcasses estimated, respectively. The Botswana Department of Wildlife and National Parks was informed of the high number of fresh carcasses seen during the survey, and an investigation into the cause of death is ongoing. Based on the ground investigations poaching has been ruled out as the principal cause, and the tusks on the carcasses were found to be intact.

4.1.3 Wildlife, livestock, and human settlement

Figures 3.57 and 3.58 provide insights into the distribution of human and livestock presence in relation to wildlife. It highlights the fragmentation and isolation of wildlife habitat that has occurred due to encroachment of human and livestock activity. This fragmentation and isolation of wildlife habitat affects connectivity and mobility of wildlife populations and can have a notable impact on the resilience of the ecosystem, making it more vulnerable to disturbances and less able to adapt to changing climatic conditions. The figures indicate that there is notably high pressure in the central Zambezi region of Namibia, which includes the Kwando and Zambezi-Chobe Wildlife Dispersal Areas. These areas are critical for wildlife movement and migration. The ratio of 1.16 wild animals to 1 domestic animal is an important metric, calculated from the results in Table 3.6, that provides a benchmark of the relative abundance of wild and domestic animals in the region. These analyses can help conservationists and policymakers identify areas where human activity and livestock pressure is increasing and to take appropriate measures to mitigate the impact on wildlife habitats. This will require a collaborative effort from all stakeholders, including local communities, governments, and conservation organizations, to ensure that the KAZA TFCA remains a vital stronghold for wildlife and a source of livelihoods for local communities.

4.2 Sampling design

The survey design, including the selection of the survey area, modifications to strata boundaries, overall sampling intensity and that of each stratum, was planned and adjusted to meet the survey objectives. The selection criteria were informed by prior knowledge and in response to challenges encountered in the field. In the following section, we evaluate the effectiveness of the criteria and the suitability of the resulting design.

4.2.1 Survey area

Nearly 47% (146,147 km^2) of the total survey area fell within the "to be determined" zone. The elephant data collected from this area yielded a population estimate of 11670 +/-3711, representing only 5% of the total estimate for the KAZA TFCA. It was anticipated that the average elephant density in this zone would be less than 0.1 km^{-2}, and the results from the survey confirmed this with an average elephant density of 0.08 km^{-2} for those strata. The two maps in Fig. 4.3 show that no elephants were recorded in the search strip in 38 strata covering 58% of the area, and that elephant density was estimated to be greater than 0.1 km^{-2} in a further 15 strata (up to 0.4 km^{-2}).

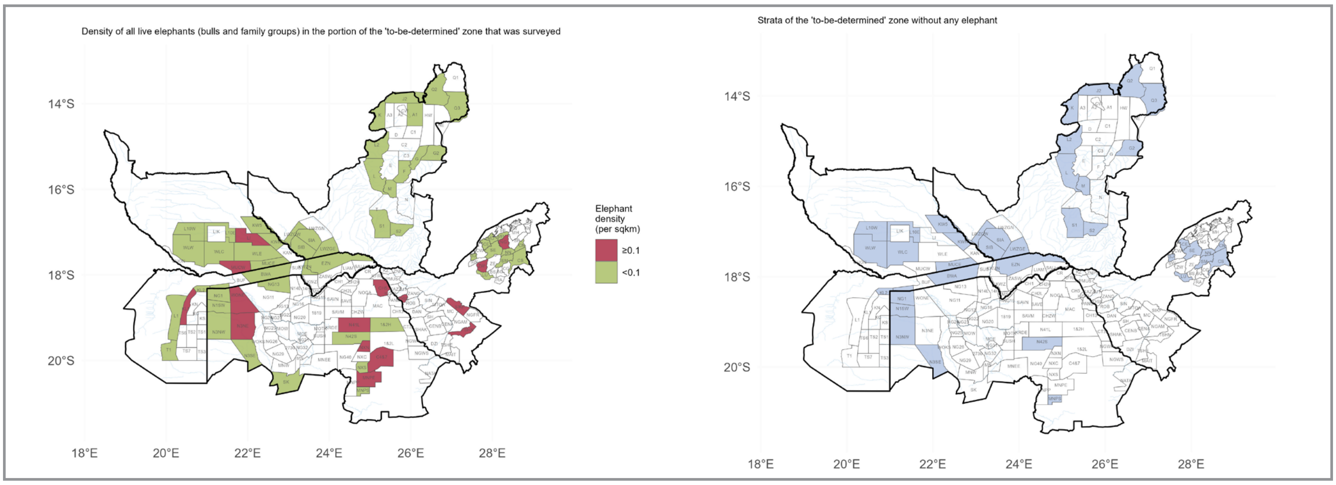


Figure 4.1: Elephant density estimates in the 'to-be-determined' zone. Left: Distribution of strata according to whether the estimated density is greater or less than 0.1 km^2. Right: Strata with no elephants in the search strip.

These results remain consistent with what was predicted and do not reveal the unexpected presence of large groups of elephants within the to-be-determined zone. Nevertheless, we would recommend extending the survey area in Botswana to include the area between the NGWS and NATA strata where elephants were seen during the survey. Multiple elephant sightings were recorded to the south of the NATA and west of the MNPP strata, although they fall outside the survey area and indeed outside the KAZA TFCA boundary. In Sioma NP, Zambia, prior consultation of available telemetry data and local knowledge should be used to locate those elephants that tend to congregate in a single herd as they may have moved out of the survey area. This may lead to planning additional strata or reconnaissance flights, as was the case during this survey.

4.2.2 Stratification

The revision of the 42 strata which took place prior to the survey, and which are shown in Fig. 4.2 was motivated by the following reasons:

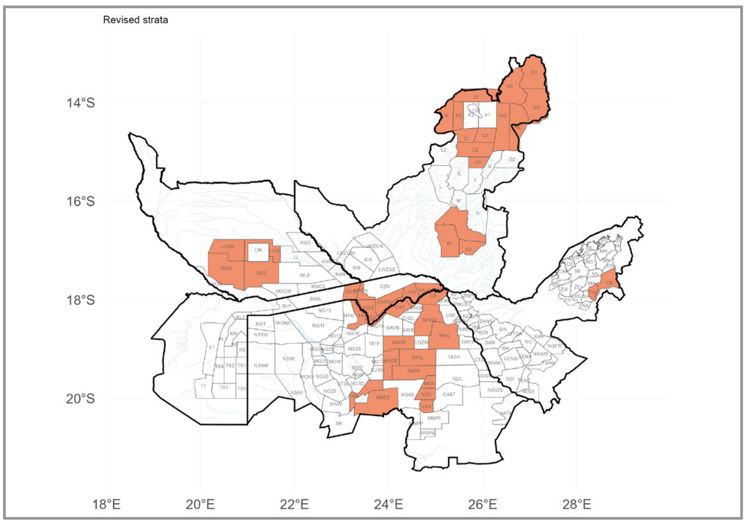


Figure 4.2: Revised strata.

1) To optimise the strata shape and size based on the distribution and density of elephants, revisions were made by incorporating the most recent available elephant distribution data into the initial stratification. These revisions were made under the assumption that these recent data accurately represented the situation during the KAZA Elephant Survey 2022. To validate the changes, the new stratification was overlaid with the elephant data collected during this survey. The results confirmed that the revisions were appropriate. However, it is important to note that some strata, such as N in the southern Kafue ecosystem in Zambia, MAC west of Pandamatenga in Botswana, and KRDE east of the Okavango Delta in the Khwai region of Botswana, exhibit noticeable heterogeneity in elephant distribution. For instance, in stratum N, elephants are concentrated in a thin strip (approximately 10km) at the northern end of the stratum, while in stratum MAC, elephants are concentrated in the east. These variations in distribution are to be expected, as they may differ from one survey to another, and it is challenging to avoid such imperfections.

2) To take into consideration the distribution and movement of elephants across the international boundary along the Kwando-Linyanti-Chobe River system, five strata were revised. These strata boundaries were extended a few kilometres beyond the river to incorporate the space known to be utilised by crossing elephants. The map in Fig. 4.3 produced from elephant data collected during the survey, confirms that these newly designed transboundary strata represented coherent units in terms of elephant distribution. For example, elephants in the CR and CH1 strata tend to cross the river from Botswana to utilise the first few kilometres of the Namibian floodplain, while avoiding venturing deeper into areas where human activity is predominant. The same can be observed in the 14H stratum, where there is a migration corridor and elephants frequently move across the border between stratum NG14 (Kwando concession) in Botswana and the Mudumu National Park in Namibia (stratum KWZ). In contrast, in the MS stratum higher densities are observed on the Namibian side of the border, in Nkasa Ruparo National Park with movement occurring back and forth across the border with Botswana.

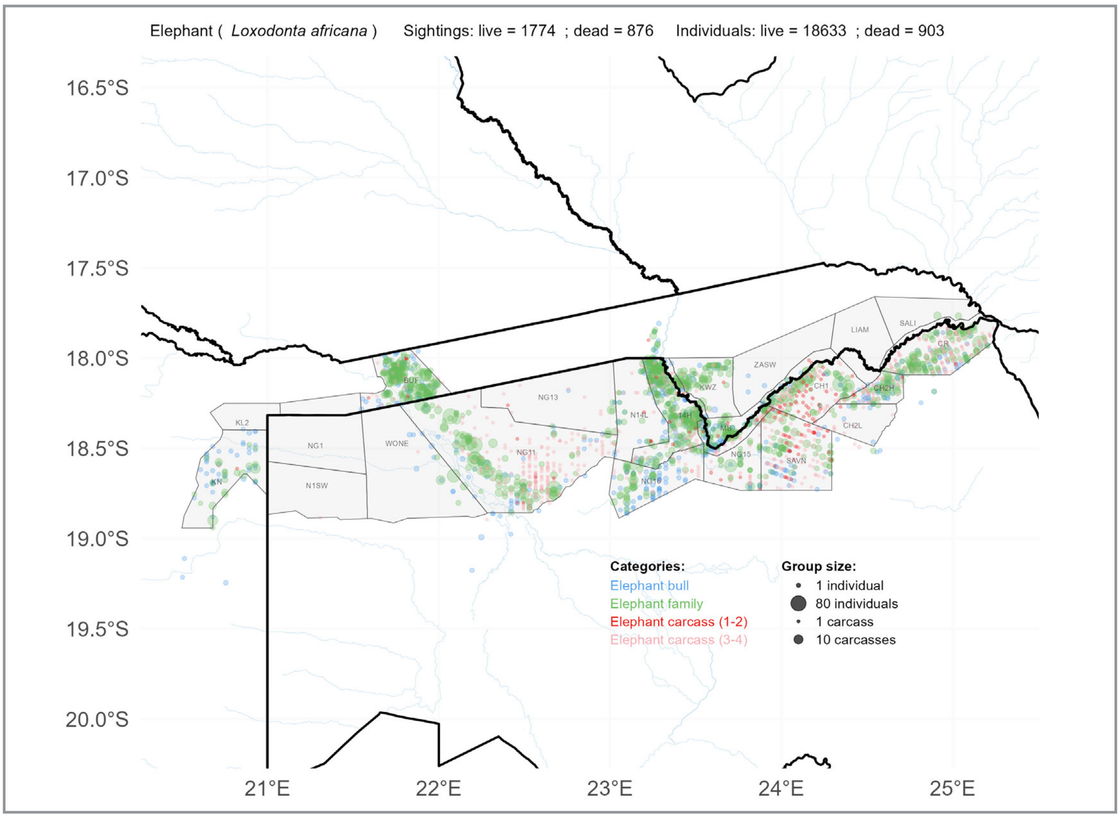


Figure 4.3: Map of elephant distribution in the transboundary strata of the Namibia-Botswana border area.

3) To optimise the flight plan and ensure that sampling could be completed in the timeframe available, the geometry of several strata, especially in Botswana, was revised, mainly by merging several adjacent strata in which elephant distribution and density was expected to be similar. In addition, particular attention was given to the length of the transects, to respect the maximum recommended time flown on a single transect to thus reduce crew fatigue. As a result:
   - the maximum recommended time of 25 minutes on a transect was exceeded only twice during the survey by 5 and 7 minutes. This represents less than 1% deviation from the standard over 2404 transects) and the variations took place on two transects in stratum NG40, northeast of Matopi, Botswana.
   - flight times ranged from 1.1 to 5.4 hours, and the recommended maximum of 5 hours per flight was exceeded for six flights (3.0%). Of these, two resulted in exceeding the recommended maximum search time of 3.5 hours per flight.

4.2.3 Sampling intensity

The KAZA Elephant Survey (2022) was designed using a top-down approach, i.e., the targets set for estimating the size of the total elephant population in the entire KAZA TFCA determined the sampling intensities of the smaller geographic units (stratum, country, and superstratum). The overall sampling intensity was 6.9%, and the percentage of relative precision (PRP) for the elephant population estimate in the KAZA TFCA was 7.3%, meeting the precision target (<10%) set for this species at this geographic scale.

The PRP achieved for elephant estimates in each superstratum in this survey was equal to or better than that of previous surveys, with the exception of south-east Angola (Table 3.1). In this region, elephants were found in large herds but at low densities. The presence of a few large herds, rather than several smaller and evenly distributed ones, tends to increase the variance and decrease the precision of an estimate. For instance, in Angola, there were only 26 observations of live elephants in the search strip, with herds varying from 1 to 112 individuals (average = 13.65, standard deviation = 23.67).

Considering the importance of the Angolan portion for elephant conservation, achieving results with improved precision is desirable. To achieve this in future surveys, we recommend increasing the sampling intensity, particularly in strata like KAN, where elephants are likely to be found. Moreover, gathering up-to-date information on elephant distribution through reconnaissance flights, if necessary, will aid in refining the final survey design.

4.3 Survey execution

4.3.1 Speed of the sampling process

The entire flight plan was designed to optimise the speed of the sampling process for each stratum, throughout the survey. Overall, the teamwork allowed for efficient sampling of each stratum, although a handful of strata would have benefited from being reduced in size or sampled using a repeat protocol. The strata that were not sampled under optimal conditions (>1 day) raised the question of whether during this extended sampling period the target elephants would have had time to move sufficiently within each stratum so that a substantial portion could have been counted twice or not at all. Given the short distances elephants travel during the dry season to stay near water, their relatively low density and their dispersed distribution in the strata concerned, we are confident that the risks discussed remain negligible without material consequences for the overall estimates.

4.3.2 Synchronisation

The scope of the survey presented the opportunity to synchronise sampling across international borders, particularly in areas where the transboundary movement of elephants is prominent. Prior to this survey, neighbouring countries conducted independent surveys in these areas at intervals ranging from several weeks to years. However, the current survey has allowed for an overview, within a comparatively short time frame, of the situation within the KAZA TFCA survey area.

On average, it took 3.9 days to synchronise the sampling of one stratum with all its neighbours. This time elapsed was minimised in the Okavango Delta, along the river system between northern Botswana and the Kavango-Zambezi superstratum and in the north-western Matabeleland superstratum, where elephant densities were highest.

Had it not been for the logistical constraints that disrupted the initial flight plan, it would have been possible to further improve this sampling synchronisation effort, particularly south of the border between Hwange National Park in Zimbabwe and Botswana, as well as at the junction of the three countries: Angola, Zambia, and Namibia. Indeed, delays in acquiring flight permits did not always allow for perfect synchronisation of flights on either side of certain international borders.

We however have a high level of confidence that sampling was achieved within a sufficiently narrow time frame to limit the possibility of material levels of double counting or omitting substantial numbers of elephants due to their cross-border movements. Detailed analyses of elephant telemetry data collected in this region during the dry season could provide insights into elephant movement patterns and speeds, and thus provide clear guidelines for future improvements to sampling schedule requirements.

4.3.3 Calibration

Pre-survey calibration exercise

For four crews, the pre-survey calibration exercise took place in a context where time management was becoming increasingly pressing, following a substantial delay in the launch of the largest portion of the survey (while awaiting flight clearances). This atmosphere likely contributed to pre-survey calibration exercises that did not fully meet the KAZA Elephant Survey standards. These standards relate to four parameters: the number of calibration passes over the marked airstrip, the coefficient of determination r^2, the intercept of the linear model, and the relative standard error (RSE) of the mean of the search strip width.

Calibration data are the result of observer and pilot performance, so we performed linear regression analysis of the data collected on either side of the aircraft as well as for the combined data. It is important to consider that if there is a loss of horizontality of the aircraft wings, it results in an increase in the search strip width on the side where the wing rises, and a decrease (though not exact compensation) on the side where the wing lowers. This explains why the data collected by the two observers are not entirely independent. By examining the combined dataset, which includes data from both the left and right sides, we can identify potential discrepancies in aircraft orientation. On the other hand, performing an analysis for each individual dataset can help pinpoint any observer who may be underperforming in their calibration exercise.

All crews except C02 and C04 had an r^2 greater than 0.75 for the combined datasets. Looking at the separate datasets for each of the observers, we observe that in both cases, the simple linear regression model did not fit the data for one of the observers well, in this case observers C02R (right side) and C04L (left side). Since the predictive power of the regression was, however, good for the other two observers, it is unlikely that these results were caused by aircraft orientation issues. C02R and C04L may have encountered difficulties in the execution of the calibration exercise or may have changed position during the exercise. With additional calibration sessions and further engagement with observers on how best to collect standardised calibration data, the predictive power of the regression models would most likely have improved, and only then should the teams have begun conducting transects.

The RSE of C03L exceeded 5%, despite an r^2 and intercept indicating reasonably good prediction of the linear regression. This is likely due to the low number of passes over the marked airstrip resulting in a small sample size. The linear regression of the right observer is based on an equally small sample size, but with a better prediction which explains the lower value of RSE. RSE can only be used to compare the samples collected by two observers within the same crew or by observers from different crews if they are of equal size. This high value of RSE should have signalled the need for additional passes and increased sample size.

Peri-survey calibration exercise

Only C05 and C07 regularly collected additional calibration data during the survey. Change of performance over time is likely to be the result of a process independent of each observer, and so these data were also analysed separately for both sides of the aircraft and combined. The results showed reduced predictive power of the linear regression models for three of the four observers and increased predictive power for C05L. This high-performing observer also has the lowest potential variation in the estimate of search trip width (C05L :146-167 m) as shown by the results of the bootstrapping analysis. These results suggest that this observer was consistent throughout the survey (r^2 equal to 0.78 and 0.80, with an intercept equal to 15 and 2). Conversely, the other three observers performed best during the pre-survey calibration exercise, which does not support the assumption that the data collection process before and during the survey remained identical.

The main biases of an aerial survey are due to the inherent difficulty of standardising the human beings who are, in the absence of alternatives such as those currently being developed by the Modernising Wildlife Surveys initiative, at the heart of the aerial survey data collection process. This relationship between the quality of the calibration results and the performance of the crew is well known, which is why it is often necessary to repeat several flight sessions between which only discussions and protocol reminders, given to the crew, suffice to obtain the expected results and adhere to standards.

When the calibration is only perceived and executed as an initial exercise, preceding the survey, then a strong assumption is made that the collection protocol during the calibration and that followed during the survey are identical or at least very similar. When comparing the pre- and peri-survey calibration data, it appears that the results were, at least for some observers, more consistent during the initial calibration exercise than afterwards during the survey.

This could be explained by the fact that:

1) crews are less prone to fatigue at the start of the survey,
2) because the validation of the initial calibration exercise conditions the launch of the survey itself, crews' attention and motivation are especially focused at this stage of the survey process,
3) an aerial survey is a challenging undertaking that human observers have difficulty performing consistently over long periods of time,
4) in the absence of continuous feedback on performance during the survey, crews are not

encouraged to look critically at their work and may unintentionally lose focus or shift it to other survey challenges and produce less standardised data.

While many of the performance visualisation tools were aimed at pilots, those aimed at observers could perhaps have been more extensive. This continuous performance feedback probably helped motivate pilots to strive for better flight standards throughout the survey. Maintaining a sustained level of concentration over several days, weeks or months requires a constant effort that could be more easily achieved if crews were continuously put on the alert.

The effort made by C04 and C05 to collect peri-survey calibration data was motivated by a desire for transparency and rigour, which in the end produced insights that weakened the results of a better initial calibration. What may appear to be counterproductive work should serve as a reminder that the results of an aerial survey are influenced by the performance of individual crew members, which cannot be perfectly standardised despite their training and experience. This was one of the reasons for conducting a bootstrapping analysis, to estimate the potential variation in the search strip width estimate for each observer and to analyse the survey results not only with the most likely search strip width, but also with the minimum and maximum estimates. The results showed that with a potential variation in the strip width estimate of 43m (281-324 m), the elephant population estimate of the KAZA TFCA would vary by 34950 individuals (217501-252451). The bootstrapping analysis considers each pass over the airstrip as equivalent. This was not the case, however, as observers refined their collection protocol over the sessions and produced better results, which is why the estimated population size (227900) for the chosen search strip width of 310 m remains the most reliable result. These insights underscore the significance of the calibration exercise and highlight the inherent challenges of conducting aerial surveys, as human observers cannot not be perfectly standardised.

We recommend implementing an additional protocol to collect calibration data throughout the survey. This would not only provide a more representative documentation of crew performance, but also enable continuous performance feedback. This approach would help to ensure observers remain more consistent throughout the survey. These considerations are even more relevant when the survey is long and strenuous.

While the data showed that an observer tends to perform calibration better during a short initial exercise than over a several-week-long survey, they also showed that some observers are more consistent than others, a selection criterion mentioned in the CITES MIKE Aerial Survey Standards v3.0 (CITES Secretariat, 2020). It is difficult to know whether an observer improves his or her consistency with experience or whether the observer in question is given new assignments based on good past performance, and therefore gains more experience. It is likely that both aspects come into play and that selecting an experienced observer with a proven track record is a safe bet. It does not exclude the possibility of recruiting new candidates provided that their endurance and the repeatability of their results are evaluated.

Due to flight permit issues, calibration exercises could not be conducted during the training and evaluation workshop prior to the survey. As a result, the assessment of observer performance was limited to visual acuity and species identification skills. To address this gap analysing the ongoing collection of calibration data during the survey itself would have been helpful. This analysis could have identified potential issues and allowed for the improvement of the data collection protocol, either through observer replacement or discussions to understand and remedy problems. This recommendation might be overlooked because sometimes calibration exercises are perceived as constraints to the execution of aerial surveys, perhaps for the following reasons:

- The time calibration exercises take is seen as time lost for the execution of the survey, which is often an ambitious exercise, pushed to the limits with very tight timetables for maximised sampling. Despite considerable planning efforts, a survey is often disrupted by factors that are difficult or impossible to control and is therefore often conducted in a context of urgency and haste.
- The absence of wildlife data collection during calibration may suggest that great efforts are being made for no result.
- While a calibration exercise follows of a well-structured protocol, its validation depends on crew performance, a variable for which control is limited and is influenced by discussions and leadership to enhance performance. This exposure to survey limitations can demotivate crews and create a desire to start the survey in pursuit of what they may perceive to be more tangible results.

Calibration exercises should be given increased attention. They should be accepted as an ongoing evaluation process and not just an initial validation. Organisers of future surveys should, from the outset of preparations and planning, allocate a comfortable amount of time for the execution of these exercises and build the survey around these necessities rather than the other way around. Additionally, we encourage the development of alternative methods to mitigate observer bias, as is already being done through the Modernising Wildlife Surveys initiative.

4.3.4 Crew performance

4.3.4.1 Observer performance

The results of the chi-square and Mann-Whitney U tests showed relatively similar results for all crews except C01. Although each observer on a crew observed a different search strip, they both flew over an area that is considered homogeneous in habitat, and therefore, statistically, the number of observations and group size estimates for each species should be similar on each side of the aircraft.

For seven of the eight crews, there were significant differences in the number of observations from 10% to 40% of the 38 species of interest. The observed differences in detection were primarily related to the following species: elephant carcasses (50% of crews), as well as duiker, impala, kudu, sable, and waterbuck (37%). C06, with only one flight and 12 species recorded, was the crew that seemed to have the highest level of consistency in detection between the observers, with duiker as the only species showing significant differences. With a few kilometres of transects, the resulting counts reflect much of the heterogeneity of species' occupancy of space. On the other hand, after several hundred kilometres of transects, these variations, observed at the local level, become smoother, and the counts reflect more the respective performances of the two observers. The results presented in Table 3.28 to Table 3.35 are thus a combination of variations in species' occupancy in space and the abilities of the observers to detect the individuals. The disparity of results among species, both within and between crews, suggest that these observers perform normally, with unavoidable individual differences, regardless of their experience and performance.

In contrast, significant differences were observed for most species recorded by C01. Furthermore, the trend seemed to be consistent with one observer systematically reporting fewer sightings (or the other systematically more) than expected given the percentage of the combined search strip allocated to each side of the aircraft. Moreover, with 456 kilometres of transects covered for C01, the statistical power is such that any imbalance would likely become detectable.

Comparison of the number of observations within each pair of observers was done regularly by the field teams and in the operation room. The imbalance that was highlighted by the chi-square test was already known at the time of the survey but was not considered sufficient to justify changing observers because:

- the differences were not as obvious when comparing two smaller sets of data,
- replacing the current observers with unproven stand-by observers offered no assurance that the results would improve.,
- a new calibration exercise would have to be conducted in a context where time was limited.

Due to the general shortage of experienced observers in the region (some of whom were unavailable as they were mobilised to take part in other planned surveys), and the unusually high number of observers required to survey the extensive KAZA TFCA survey area, we had limited flexibility in selection. Moreover, determining which of the two observers is under-performing is not always possible. It may be that the one observer announcing less detects less than he should, yet the one announcing more could also erroneously be counting observations outside the sample area. We therefore preferred to continue with the experienced observer, who took part in the pre-survey selection workshop during which their eyesight and species knowledge were evaluated, as recommended by the CITES MIKE standards. The two stand-by observers, however, served as a back-up to replace the observers on duty in case of any unforeseen departure from the survey.

4.3.4.2 Pilot performance

The piloting of the aircraft has direct consequences on the quality of the data collected by the observers. Stable, level flight results in equivalent search strip widths for both observers. Some equally important considerations regarding flight height and speed also come into play. A target flight height of 91 m (300 ft) with a standard deviation of less than 10% ensures an optimal combined search strip width of 300 m (assuming perfect calibration). Flying at higher heights leads to an increase in search strip width, increasing the area the observer must search in the same amount of time, and observations further away from the aircraft become more difficult to detect and count for the human eye. On the other hand, flying lower results in a reduction of the search strip width and thus of the sampling intensity required to obtain sufficient precision of the final population estimate. A flying speed inferior to 180 $km.h^{-1}$, provides sufficient time for observers to detect and count the passing groups of animals, and a target speed of 170 $km.h^{-1}$, if the height standards are met, provides a search effort slightly greater than 1 $min.km^{-2}$

The histograms showed that for each pilot the distribution of height and speed are clearly concentrated on the target values, with a low dispersion, indicative of consistent piloting of the aircraft. The standards are required to be met for each transect, which is why the performance results presented in Table 3.23 are for the means and standard deviations of height and flight speed per transect, and not for the aggregated data set. The mean flight height per transect was 91.8 metres, with a mean standard deviation of 6.5 metres, and the mean flight speed per transect was 171.5 $km.h^{-1}$, with a standard deviation of 5.8. This resulted in an average search strip width of 310 metres for the entire survey.

These results, presented for each pilot show some nuances, with notably only 18% of the Sebungwe transects (P06) meeting the flight height consistency standards. This is due to the absence of continuous height data collection during the flights, in contrast to the other pilots who were able to provide a measurement every second, using the Flightlogger laser altimeter output file. This reduced sample led to the calculation of averages and especially standard deviations that may not be representative of the flights. Added to this are the more challenging flight conditions in this region with the more rugged terrain of the KAZA TFCA.

Overall, adherence to the standards is sufficiently achieved, a result that is even more commendable considering the pilots had demanding schedules, flying for extended periods over weeks or months, with very little flexibility for weather considerations. It is likely that the daily feedback on performance helped motivate the pilots to strive for better flight standards throughout the survey. The collective examination of these results, in which crews could compare their performance against each other, may have encouraged an atmosphere of good-natured competition in which everyone was constantly trying to improve.

Transects for which flight performance was suboptimal were mapped in Appendix 13 and are shown in red. This deviation from the standard may be in some cases small and these maps do not reflect their magnitude. More information is however provided in the second volume of this report which compiles detailed summaries of the survey of each stratum.

Since the flight performance and adherence to standards was found to be high, conducting the recommended ANOVA analyses to investigate possible causes of performance loss is largely unnecessary. The flight data collected at one-second intervals generated large datasets, and provided a high statistical power, making ANOVA tests very sensitive. The likelihood of detecting very subtle differences between the categorical variables considered (pilot, aircraft, strata, flight) was therefore high, which explains why all results came back as significant. Insights into these subtleties are of no practical use for our performance evaluation, and the evaluation of the mean and standard deviation of flight height and speed per transect was sufficient.

4.3.4.3 Other crew roles

The quality and reliability of data collected by crews is commonly assessed through the evaluation of pilot and observer performance, ignoring the impact that the rest of the team, especially the data managers, have on the process of managing a large database. Given the size of the survey and the daily work rhythm, each crew had one or more data managers, responsible for downloading, transcribing, interpreting, and archiving the data. They were also responsible for performing preliminary analyses to provide daily feedback on crew performance. This role proved to be crucial for the smooth running of the survey. It is recommended that a data manager be systematically integrated into crews for future surveys and that a rigorous selection process be considered, in addition to those established for pilots and observers, to ensure that the individuals identified for this role have proficiency in statistical software and demonstrate a high level of scientific rigour.

4.3.5 Photo interpretation

The use of cameras and photo interpretation has become a standard practice in the analysis of aerial survey data in recent years, serving to address, at least in part, the inevitable inaccuracies in group size estimates generated by observers. However, little information is usually provided in the reports about how this process is carried out, a shortcoming that is even more important because this process is based on a protocol that requires interpretation and thus incorporates a certain subjectivity in the analysis of the results. Whilst the process could be improved, the results show that the corrections made resulted in a 2.2% increase in the estimated population of elephants in the KAZA TFCA survey area.

Of all the elephant sightings requiring photographic interpretation, 42.5% could be matched to a photograph. This is a baseline percentage that should be attempted to be increased in future surveys. Furthermore, while it is straightforward to increase a count when the photograph shows a greater number of individuals than the observer reported, the reverse is not always the case, as the reliability of the photograph must first be assessed. If the image was considered reliable, i.e., it was in focus, well-framed and vegetation did not cover the observations, then the image count was used. The positioning, setting, and handling of cameras was not a simple task, and we encourage future surveys to establish a clear protocol and to invest into staff training, to maximise the number of usable images collected.

The assessment of images is preferably conducted shortly after the flight by the observers themselves, as they possess the contextual information. However, the decision to replace traditional cameras triggered by observers with high-resolution cameras from the Modernising Wildlife Surveys initiative on three of the aircraft, capturing continuous photos every two seconds, made this approach infeasible. The significant number of images, which could only be linked to observations through their photograph timestamps, substantially slowed down the process, rendering field-based assessment impossible. Subsequently, data managers were responsible for interpreting the photographs in the weeks after the survey, lacking the contextual knowledge of when the images were taken. We recommend that future survey teams facilitate prompt evaluation of images by the observers immediately after the flight.

5 CONCLUSION

5. Conclusion

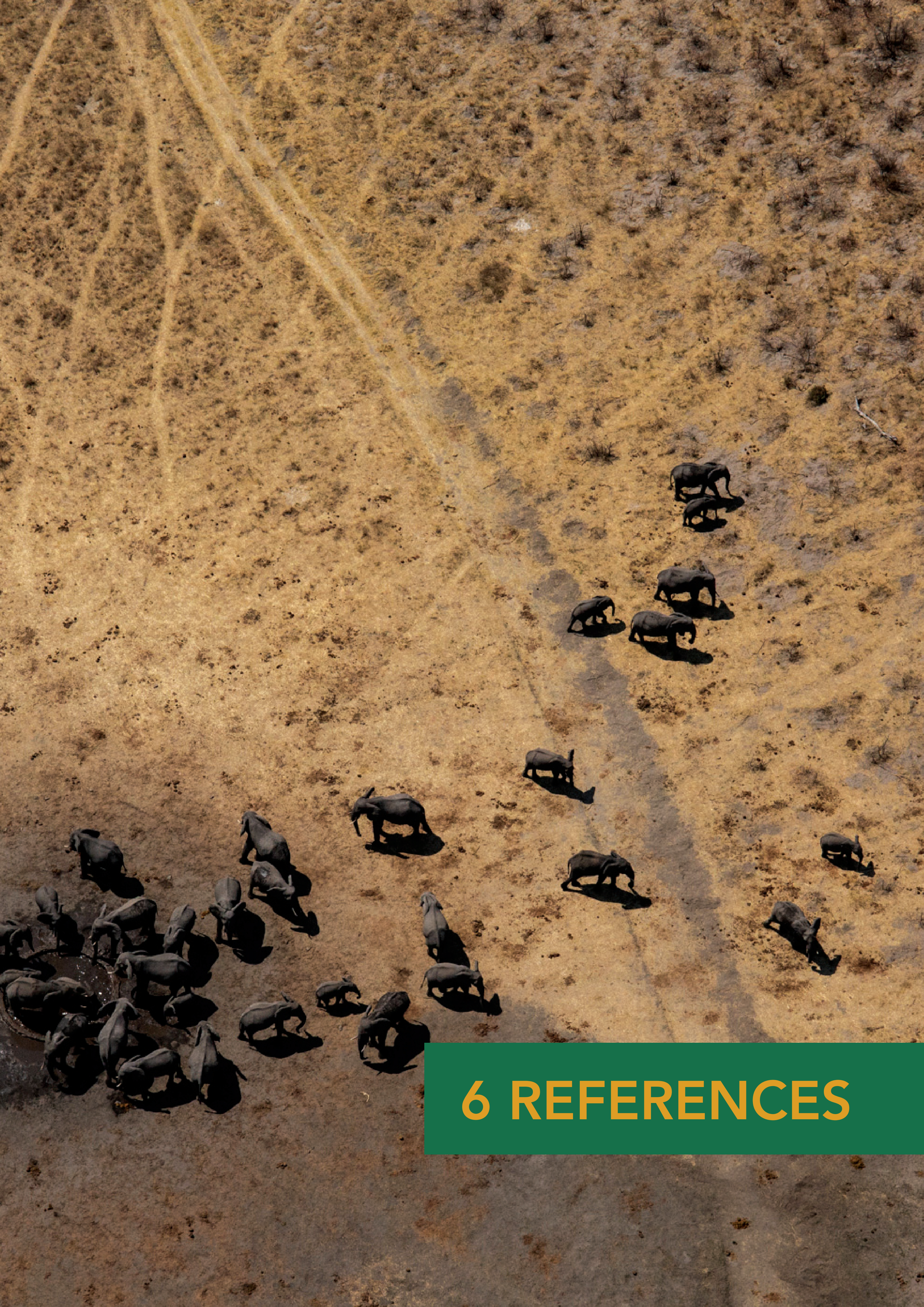
This survey was initiated in response to the need for a synchronised aerial survey of elephant populations across the KAZA TFCA. Its primary objective was to establish an estimate of the elephant population in the KAZA TFCA. In the face of increasing habitat loss and climate change, maintaining spatial connectivity and implementing unified conservation strategies across national boundaries is crucial to ensure ecosystem resilience.

The survey was a pioneering effort that faced numerous logistical and operational challenges. Its exceptional scale, the short time frame for its completion, the mobilisation of seven aircraft and nine crews, the need for standardisation of materials, methods, and protocols, and synchronisation of efforts across five countries, each with different administrative procedures for acquiring the necessary authorisations, all contributed to the complexity of the undertaking.

The successful completion of the survey represents an important achievement for wildlife conservation and management in the region and is a testament to the collaborative atmosphere fostered among various stakeholders and demonstrates that it is possible to address complex issues at large scales through close cooperation.

Considerable effort was invested at each stage of the project and throughout the survey to critically evaluate the methods and ensure the reliability of the results, with the goal of optimising performance and quality. This technical report provides comprehensive documentation of this process, including the planning and execution of the survey, the analysis of the results, and the discussion of its strengths and limitations. The report's transparency and attention to detail serve as a blueprint for future surveys, empowering teams to build on the experiences gained, all of which is summarised in Appendix 14 in the form of lessons learnt.

Finally, the KAZA Elephant Survey (2022) has generated crucial data that provide invaluable insights for future conservation efforts in the region and beyond, specifically for the conservation of elephants and their habitats. We urge all stakeholders to leverage this information and continue collaborating to address the complex conservation challenges to ensure the long-term survival of this keystone species and the rich biodiversity they support.



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7 APPENDICES

7. Appendices

Appendix 1: Evaluation and training workshop

A training and evaluation workshop in preparation of the KAZA Elephant Survey (2022) was held at the Travelodge in Kasane, Botswana, from the 20th to the 26th of July 2022. It was coordinated by the KAZA Secretariat. A detailed account of the planned activities and the anticipated participant evaluation process can be found in the workshop curriculum and program (Bussière, 2022b).

This workshop was initially motivated by two expectations: 1) to recruit the qualified personnel needed to conduct the survey and 2) to provide capacity building in aerial survey techniques to the partner states of the KAZA TFCA. When the coordinating team was put in place in February 2022, there were six months left to launch the survey in time for the dry season. Given this time frame and the difficulties encountered in recruiting a workshop trainer, it seemed ambitious to meet both above expectations for the upcoming workshop. Thus, the coordination team, supported by some aerial survey experts, assumed the role of trainers and the workshop had, as its primary objective, the training and selection of rear-seat observers nominated by the five partner states, secondly, getting everyone aligned on the objectives and the standard operating procedures, and thirdly, hosting a larger number of partner state nominees to build capacity and strengthen their knowledge of aerial survey techniques.

Seventy-two people, including reception staff and the press, were present at the workshop, with four aircraft provided for the survey simulation modules. However, unexpected difficulties in the process of acquiring flight permits did not allow the practical flight modules to take place. This setback, which until the last moment seemed to be solvable, required a major revision of the practical modules of the workshop. Of the four that were planned, only the species identification module and the first aid course could be carried out as planned. The survey flying module had to be cancelled and the data transcription module, which was based on data collected in flight, had to be completely revised. Two other modules were then proposed to replace the flight, starting with 1) the "aerial survey and sampling theory game" which offers an engaging and playful approach to elucidate the principles of aerial surveys (WWF, 2000), and 2) a second module that involves a flight simulator, wherein four individuals assume the roles of a survey crew seated on chairs, simulating their participation in an aerial survey.

These changes in the programme meant that the criteria for the evaluation and selection of participants had to be adapted. At the time of the workshop, the two contractors selected to carry out the survey had already identified some of the staff who would make up the different crews. The people in question had qualities and experience relevant to the roles for which they had been selected. An inspection of their CVs and interviews confirmed the relevance of these choices. Nevertheless, it was still necessary to select ten rear seat observers and three front seat observers, whereas the pilot positions were already filled. The role of data manager was, at that stage, considered optional. The workshop had therefore not been planned to allow participant assessment with a view to filling these yet unconfirmed positions. The large number of participants and the limited capacity of the trainers also meant that not everyone could be assessed. Only those participants who met all the eligibility criteria for the workshop took part in the various tests concerning quality of vision, knowledge of species identification, attitude, motivation, and attendance. Although the workshop did not include tests to assess front seat observers, the presence of highly qualified and experienced staff for this role at the workshop proved sufficient to fill these positions.

The cancellation of the survey flying module, in addition to creating disappointment among the many participants, did not allow for an assessment of the participants' flying qualities and of their ability to carry out the necessary calibration exercises before launching a survey. Also, for the same reasons, participants who were unable to demonstrate previous flying experience were eliminated at the risk of being sick in flight.

Despite many setbacks and last-minute improvisations, the workshop went ahead, and the participants were duly evaluated and selected. Rear Seat Observers were chosen through a selection process that considered various factors, including availability over the survey period, COVID-19 vaccination status, survey experience, species identification module score, eye test scores, as well as a subjective assessment by the trainers on attentiveness, energy, and overall good will. Of the 35 RSO candidates evaluated, the top scoring 12 that were available were selected to participate in the survey, with two of those serving as stand-by RSOs. Additional RSOs were provided by the subcontractors based on considerable prior experience.

Table A1.1: Results of the rear seat observer selection for the participating crews.

Crew	Side	Final Rank	Availability confirmed	COVID vaccination	Prior Experience (hours)	Eye score	Species ID module score	Evaluator perception	Sampling Practice Module	Data Capture Module	First Aid Course
C05	L	1	Yes	Yes	840	92	78	94	Yes	Yes	Yes
C08	R	2	Yes	Yes	500	86	70	91	Yes	Yes	Yes
C04-C05-C06	R	3	Yes	Yes	1400	91	76	91	Yes	Yes	Yes
C07	R	4	Yes	Yes	150	84	68	90	Yes	Yes	Yes
C02	R	5	Yes	Yes	411	95	76	90	Yes	Yes	Yes
C01	R	6	Yes	Yes	100	79	75	88	Yes	Yes	Yes
C07	L	7	Yes	Yes	600	81	77	87	Yes	Yes	Yes
Stand-by		8	Yes	Yes	1700	91	69	85	Yes	Yes	Yes
Stand-by		9	Yes	Yes	300	95	78	81	Yes	Yes	Yes
C03-C04	L	10	Yes	Yes	600	79	60	78	Yes	Yes	Yes
C01	L	13	Yes	Yes	1000	60*	47	74	Yes	Yes	Yes
C06	L	14	Yes	Yes	93	85	66	74	Yes	Yes	Yes
C03	R	DNA	Yes	Yes	2758	**	-	-	No	No	No
C09	Both (block count)	DNA	Yes	Yes	***	**	-	-	No	No	No
C08	L	DNA	Yes	Yes	219	**	-	-	No	No	No
C02	L	Not assessed	Yes	Yes	800	**	-	-	Yes	Yes	Yes

* Required corrective lenses, and to provide a new eye test prior to commencing survey.
** Provided satisfactory private eyesight assessments.
*** Previously conducted the block counts in the Sebungwe region.

Participant feedback on the workshop was generally very positive. Their responses to the closing questionnaire rated for each module: 1) the relevance of the activities proposed, 2) the length and design of the module, 3) the clarity of the objectives and instructions, 4) the possibility for participants to interact with the trainer, and 5) the quality of feedback provided by the trainer. The average score for the whole workshop was 3.55/5, based on the scores of 47 participants. Details of the scores by module are provided in Fig. A1.1.

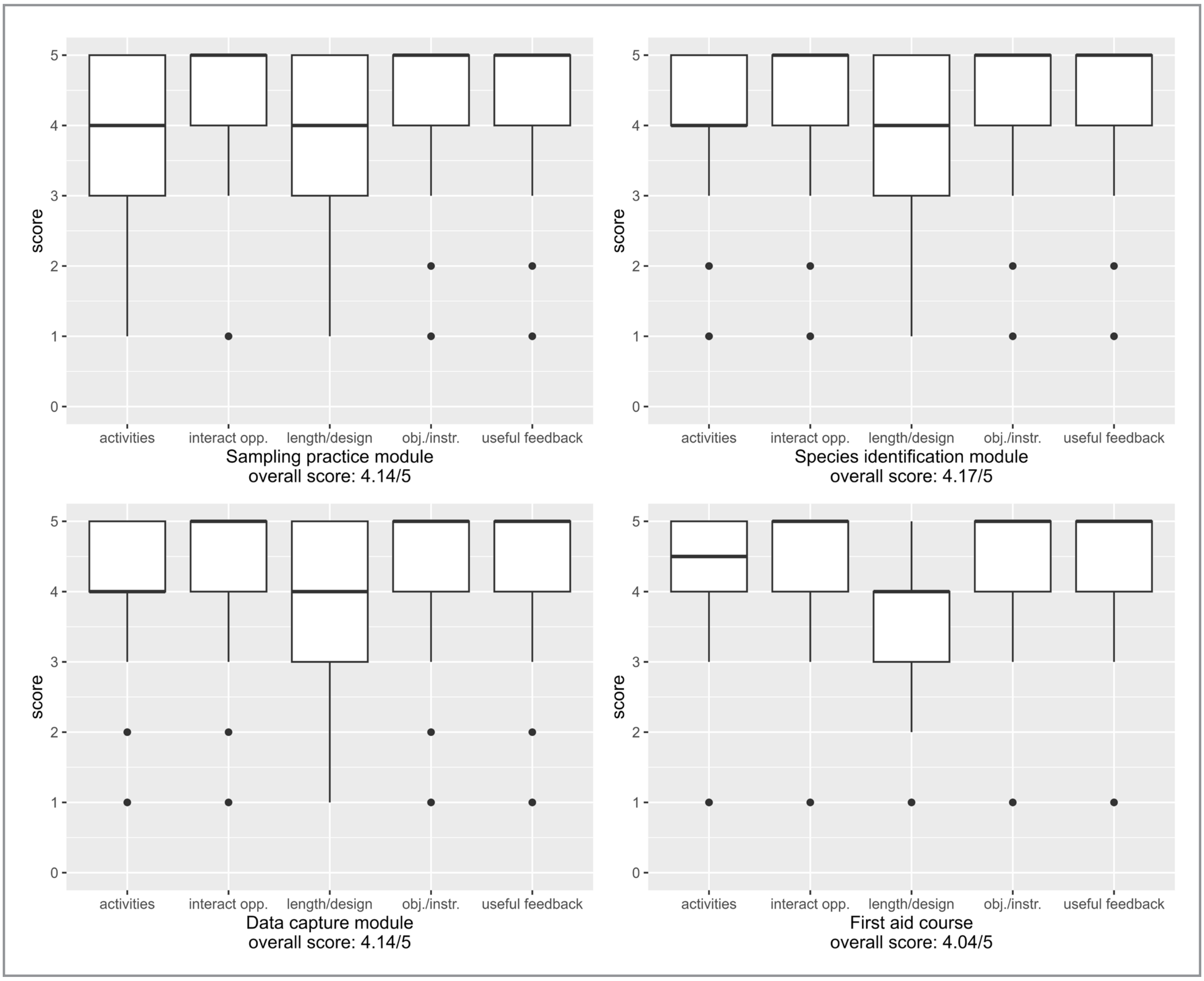


Figure A1.1: Scores given by 47 participants in the four different practical modules offered at the workshop.

Table A1.2: List of trainers for the four practical modules

Trainer	Module
Dylan Blew	Species Identification
Lesedi Tsholofelo (Emergency Assist 911)	First Aid Course
Dr Debbie Gibson and Dr Kevin Dunham	Sampling Practice
Dr. Elsa Bussière	Data Capture

The results of the workshop's closing questionnaire also made it possible to list the subjects of interest for which there is still an expectation of training for the governmental personnel of the partner states. These results are presented in Fig. A1.2.

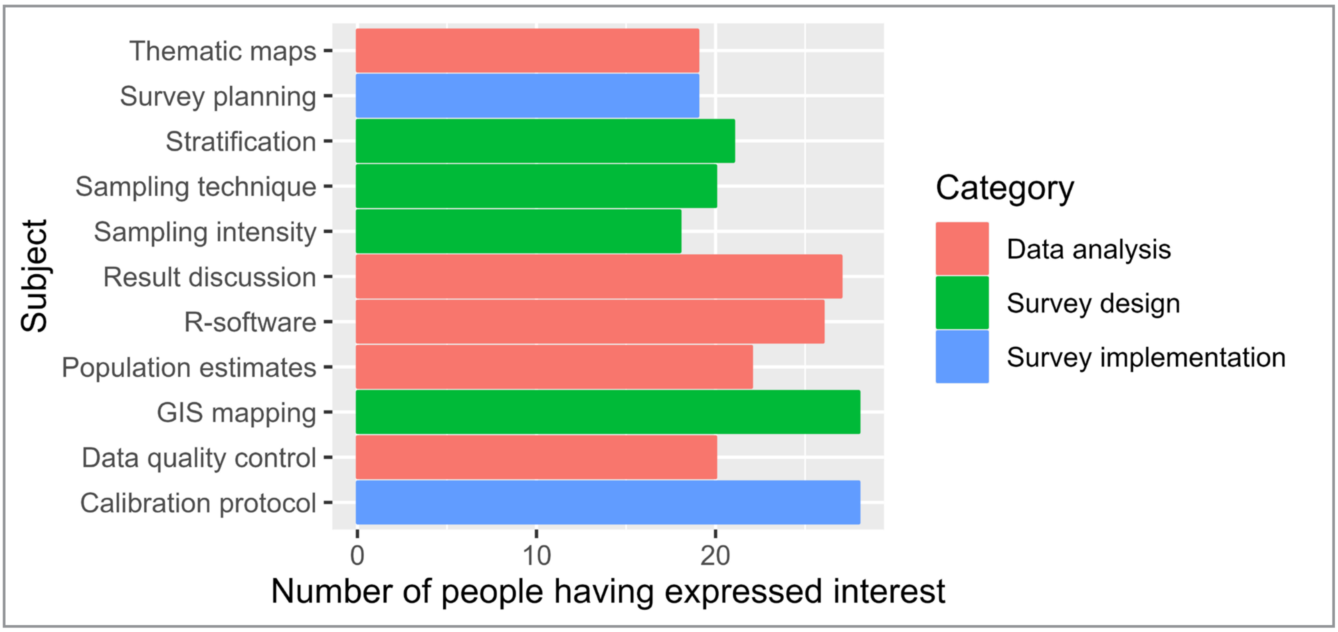


Figure A1.2: A bar chart illustrating the topics in which the workshop participants would like to be trained.

The results of the selection were then communicated to the focal points of the different partner states, and no withdrawals were made.

Once the need for data analysts to ensure the operationality of the operations room was confirmed, the results and notes taken during the workshop, and specifically at the data capture module, proved to be very useful in identifying the right people for this role.

Figure A1.3: Photographs of the training and evaluation workshop in Kasane, July 2022. Top: Sampling practice module. Bottom left: Data capture module. Bottom right: Species identification module.

Fig A1.4: Photograph of the participants at the training and evaluation workshop in Kasane, July 2022.

Appendix 2. Calculation of the baseline

Using the distgeo function from the geosphere package in R software (Hijmans R, 2022, R Core Team, 2022), the baseline (maximum length of a stratum, perpendicular to the transects of this same stratum) was calculated, prior to applying the Jolly's method 2 (1969). The maximum east-west distance of the stratum was calculated when the transects were oriented north-south, and the maximum north-south distance when the transects were oriented east-west. To ensure that the transects were aligned perpendicular to the ecological gradient, orientations other than the typical north-south or east-west were required in 38 of the strata. In these cases, the following protocol was followed:

1. Rotation of the stratum around its centroid, counter-clockwise, by an angle equal to the orientation of the transects.
2. Mapping of the longest segment that crosses the rotated stratum along its east-west length.
3. Rotation of the segment, around the stratum centroid, clockwise by an angle equal to the orientation of the transects, thus placing the segment along the stratum as it would be in its original position.
4. Calculation of the length of the newly positioned segment using the distgeo function.

An example of this process is presented in Fig. A2.1.

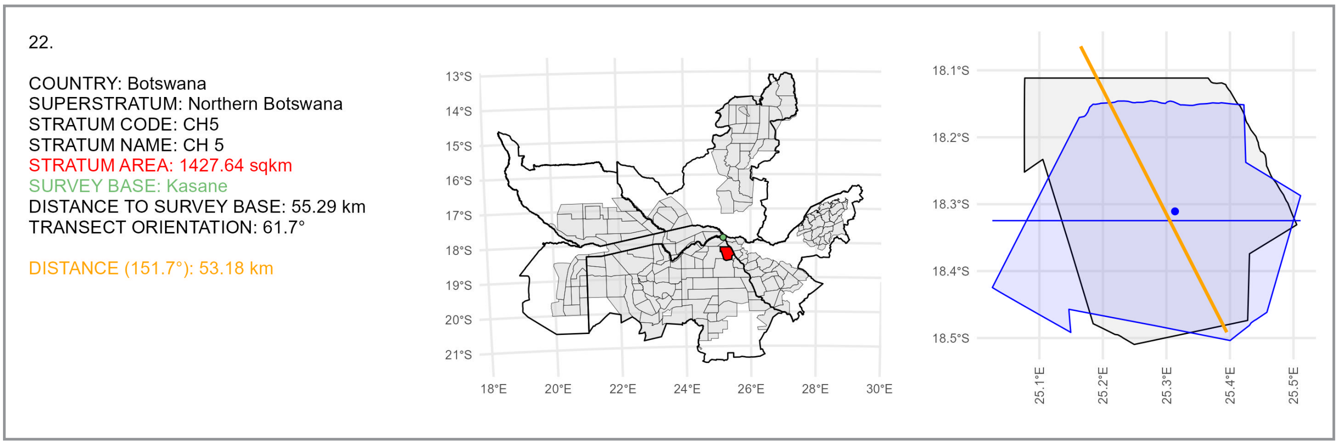


Figure A2.1: Calculation of the length of the baseline for stratum CH5 in northern Botswana.

Appendix 3: Operations room

The KAZA Elephant Survey (2022) Operations Room was set up in the former conference room of the Kasane wildlife office, located near the KAZA Secretariat office in the heart of the KAZA TFCA. The room underwent a complete refurbishment to ensure its suitability for the survey's needs. It was equipped with backup electricity and internet to ensure uninterrupted communication and monitoring of all activities throughout the survey. The room was staffed by three to six data analysts, who were carefully selected based on recommendations, their CVs, and interviews. Notes taken during the data capture module of the workshop were also considered when choosing analysts. The team was under the direct supervision of the science and technology manager and the survey coordinator to ensure optimal performance.

Real-time aircraft tracking and safety systems

To ensure safety during the operation, all aircraft were equipped with Garmin InReach satellite communication devices that allowed for continuous tracking of crew positions at two-minute intervals. The EarthRanger platform was used by the coordination team to centralize and map this information, which was then projected on screens in the operations room. This real-time bird's eye view facilitated the implementation of safety systems and helped to ensure prompt and controlled responses to any incidents, which was vital given the risks involved in the operation.

Flights were conducted at a height of 300 feet above ground, which presented considerable hazards, including bird strikes, obstacle collisions, and the reduced opportunity to recover control of the aircraft in the event of a stall or engine failure. Pilots had a high workload as they navigated these hazards while adhering to survey parameters such as trajectory, height, and speed. Moreover, the operation took place in remote wilderness environments, compounding the risks to the safety of crews.

To minimize these risks, strict criteria for aircraft safety and pilot competency were established. The pilots were required to hold a commercial license, have experience in low-level survey flying, and be experienced in flying in remote areas with bush landing strips. Additionally, flight following, and emergency response protocols were put in place to further enhance safety.

Two-way communication line and support

The Garmin InReach satellite communication devices allowed for a two-way messaging capability between the field teams and the operations room, even in remote and isolated areas. This meant that the coordination team could quickly provide support if the ground teams encountered any difficulties.

Data quality assurance

Data collected in the field during the survey was regularly sent to the operations room, where the dataset was then reviewed to ensure that 1) it was complete and transcribed in a rigorous and accurate manner, 2) the flight parameters were respected (assessment of the pilots' flight performance), and 3) all rear-seat observers' performance met the standards. For some crews, these evaluations had already been carried out in the field following each flight. However, they were repeated in the operations room to validate the flights and to archive the data collected. These data could then be curated and prepared for the final analysis. An example of the data visualisation tools is provided below for the Shapi stratum (SH) of the north-west Matabeleland superstratum in Zimbabwe. Those for all other strata in the survey are provided in Volume II of the report.

Survey coordination

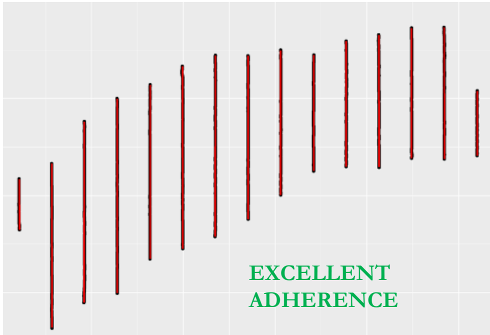
EarthRanger, a real-time domain awareness system, allowed for a comprehensive view of the KAZA Elephant Survey (2022) in real-time by integrating all operational elements. This facilitated the efficient coordination of security systems, personnel, and response options. The daily progress of all teams was monitored and recorded using a geographic information system (GIS). The design was checked for conformity and preliminary data were visualised.

Data hub

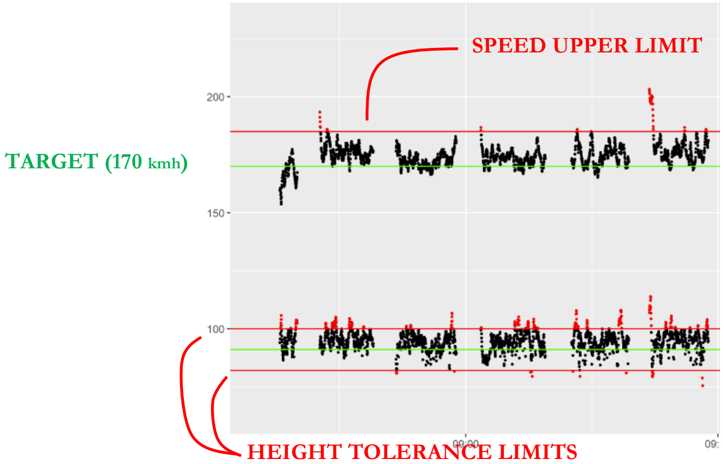
The operations room evolved into a data hub, thanks to the technical proficiency of the data analysts. The analysts not only centralised, organised, and archived information but also scanned, cleaned, corrected, and prepared it before conducting a final analysis. Despite considerable efforts to standardise data collection procedures and protocols prior to the survey, the team's datasets had to be adjusted to be consolidated into a single database. Furthermore, overflight of a stratum by several aircraft and overflight of several strata during the same flight required substantial efforts to reorganise the information to allow analysis by stratum. In some cases, technological device malfunctions, such as the laser altimeter, required continuous adaptation of the arsenal of tools (R, GIS) used for analysis. The examples in Fig. A3.1 represent some of the work done in the operations room.

Figure A3.2: Photographs of the operations room in Kasane, Botswana.

Flight: V5LJB20220905A
Stratum: Shapi (SH)
Superstratum: N-W Matabeleland
Country: Zimbabwe
Sampling: 15 transects, 244 km



TRAJECTORY CHECK:
The flight plan (red line) and the actual flight path (black line) were compared to ensure that adherence to the path of each transect was maintained.



SPEED AND HEIGHT CHECK:
The data concerning the speed and the height were dissected, for each transect, to evaluate the flight and thus the quality of the data collected. Horizontal red lines are the limits of tolerance for these variables; the green lines, are target values.

LEFT OBSERVER
52,7%

BALANCED OBSERVATIONS

RIGHT OBSERVER
47,3%

OBSERVER CHECK:
The percentage contribution of each of the two observers to the total count was calculated. When the percentages were in the range 45% - 55%, the contributions were balanced, and the target was reached.

Figure A3.1: Performance feedback example for stratum Shapi (SH) in north-west Matabeleland, Zimbabwe.

Appendix 4: Logistics and practical considerations

The flying aspect of the KAZA Elephant Survey (2022) was a massive undertaking that spanned over two months, with teams operating from sixteen bases across five countries. A total of seven different aircraft were used to cover the vast area, resulting in ~700 hours of flight time, with an eight aircraft used as liaison and to conduct two of the three reconnaissance flights. To accomplish this feat, ~50,000 litres of avgas had to be carefully positioned to ensure that the aircraft could continue flying without interruption. Accommodations and ground logistics for the 47 participating crew members also had to be arranged. Furthermore, to conduct the survey, permits had to be obtained from the relevant authorities in each of the five countries. This process required considerable effort and attention to detail to ensure that all necessary permits were obtained in a timely and efficient manner, allowing the survey to proceed as planned. To facilitate future attempts at replicating this survey, we have included in this Appendix the details of the fuel logistics and permit application process that we followed.

Fuel acquisition and distribution

We faced challenges in obtaining new empty 200lt fuel drums in Zimbabwe, so we had to have them manufactured in South Africa and imported into Zimbabwe. The required number of drums were then filled at Charles Prince International Airport in Harare before being distributed to Rokari in the Sebungwe region. The remaining empty drums were transported to Victoria Falls where they were filled at the international airport before being transported to the Main Camp and Robins bases in north-west Matabeleland.

In Botswana, fuel and drums were purchased from Puma Energy and transported from Kasane, Francistown and Maun to the relevant survey bases. Flying Mission Zambia provided the drums and avgas in Zambia which they transported from their Lusaka base to the Chunga, Ngoma and Sioma survey bases. In Namibia, however, it is not permitted to transport fuel in drums and so we made use of the services of Rundu Service Centre who supplied fuel in tailer bowsers that were positioned at Immelmann, Divundu, Rundu and Tsumkwe survey bases at the necessary times during the survey.

Table A4.1: Summary of fuel distributed to bases during the survey:

Country	Base	Drums used	Litres used
Botswana	Pandamatenga	7	1400
Botswana	Sowa Pan	1	200
Botswana	Motopi	10	2000
Botswana	Gumare	11	2200
Botswana	Khwai	9	1800
Botswana	*Pumps*		4704
Namibia	*Fuel Bowser*		9381
Zambia	Chunga	41	8200
	Ngoma	12	2400
	Sioma	10	2000
Zimbabwe	Umtshibi	13	2600
Zimbabwe	Rokari	16	3200
Zimbabwe	Robins	7	1400
TOTAL		137	41485

Overflight and landing permits

Private aviation operations in Southern African nations are governed by the respective Part 91 of the Civil Aviation Regulations, which outline the regulations for non-commercial flights, including pilot certification, aircraft maintenance, and flight operations. Typically, private flights are conducted for personal or business use and do not involve compensation.

Commercial aviation operations, on the other hand, are regulated by Part 121 of the Civil Aviation Regulations and involve the transportation of passengers or cargo for compensation. This includes scheduled and non-scheduled air services, charter flights, and air taxi operations. Commercial air operations are subject to more rigorous regulatory requirements related to crew training, maintenance, operations, airworthiness, and safety management.

Not-for-profit aerial surveys of wildlife typically fall under the regulations for private or non-commercial operations, depending on the country in which the survey is conducted and the nature of the survey itself. It is essential to consult with the relevant regulatory authorities and obtain any necessary permits or approvals before conducting the survey.

For instance, the coordination team was advised by the Civil Aviation Authority of Botswana that the survey would need to be conducted under Part 121, which mandates obtaining an Air Operator Certificate (AOC). The AOC process involves demonstrating compliance with various regulations and requirements related to airworthiness, crew training, maintenance, operations, and safety management. This made the application for permits for the selected operator to conduct the survey in Botswana considerably more complicated.

To overcome this challenge BushSkies applied to operate their aircraft under the existing AOC of WestAir (Pty) Ltd. from Windhoek, Namibia. This required application to the Namibia Civil Aviation Authority to add the aircraft to the license and issuance of Operations Specification certificates for each aircraft. The pilots also had to undertake additional training, and for each flight conducted, a risk assessment had to be carried out.

Additionally, national aviation authorities may insist on using local operators for the survey flying, by applying cabotage rules, to protect their local aircraft operators and revenue stream. In such cases it is necessary to prove that no local operators are available with the necessary equipment and experience to conduct the survey.

Table A4.2: Provides details of the permits acquired for the survey:

Country	Authority	Permit Number	Date of Issue
		0377/2022	19/10/2022
Angola	Autoridade Nacional de Aviação Civil	015/2022	19/10/2022
		014/2022	19/10/2022
Botswana	Civil Aviation Authority of Botswana	CAAB 7/5/4/ XVI (58)	08/09/2022
Namibia	Namibia Civil Aviation Authority	*Not specified*	23/09/2022
Zambia	Zambia Civil Aviation Authority	CAA/104/13/280	03/08/2022
		DCL 1478/22	25/08/2022
Zimbabwe	Civil Aviation Authority of Zimbabwe	DCL 1479/22	25/08/2022
		DCL 1480/22	25/08/2022

In the following section we outline the requirements for each country to obtain the necessary permits to conduct the aerial survey. In each case the process took several months to be approved.

Angola

1. Letter of authorisation from the Instituto Nacional de Biodiversidade e Conservação (INBC).
2. Letter of Support from the KAZA Secretariat.
3. Map outlining full routing that the aircraft will be flying (with coordinates), clearly showing the entry and exit crossings into Angola.
4. The time frame in which the flights will be conducted, including a detailed flight schedule with operational bases.
5. Full names & designations of all persons on board.
6. Aircraft documentation:
   a. Current certificate of airworthiness,
   b. Current release to service,
   c. Current certificate of registration,
   d. Current aircraft certificate of insurance,
   e. Current radio licence,
   f. Current Air Operators Certificate and, if applicable, Aerial Works Operator Certificate (AOC/AWOC).
7. Crew Documents:
   a. Current licences,
   b. Current medicals,
   c. Current Passports.

The Civil Aviation Authority (ANAC) seeks final approval from the Ministry of Defence before issuing any overflight and landing permits.

Botswana

1. Letter of intent from the Air Operators Certificate (AOC) holder, stating proposed dates and areas of operation, aircraft type and registration and name(s) of pilot(s).
2. Letter of application from the contractor (i.e., WWF and KAZA).
3. Letter of endorsement from the Department of Wildlife and National Parks.
4. Letter of Support from the KAZA Secretariat.
5. The time frame in which the flights will be conducted, including a detailed flight schedule with operational bases.
6. Entry and exit routes, i.e., Flight Information Region (FIR) boundary crossings.
7. Map outlining full routing that the aircraft will be flying (with coordinates).
8. Full names & designations of all persons on board.
9. Aircraft Documents:
   a. Current certificate of airworthiness,
   b. Current release to service,
   c. Current certificate of registration,
   d. Current aircraft certificate of insurance,

    e. Current radio licence,
    f. Current AOC/AWOC.

10. Crew Documents:
    a. Current licences,
    b. Current medicals,
    c. Current Passports.

The Civil Aviation Authority (CAAB) seeks final approval from the Ministry of Defence before issuing any overflight and landing permits.

Namibia

For the Namibian portion of the survey, only Namibian registered aircraft operating under BushSkies/WestAir were used, and therefore no Overflight and Landing Permits were required. It is important to note that flying under 500ft is prohibited and obtaining a special permit and NOTAM (notice to all airmen) publication is necessary to fly at lower altitudes. This process to obtain special permits from CAA can take several months. To apply for the permit the following documents are required:

1. Letter of Support from Ministry of Environment, Forestry and Tourism.
2. Letter of Support from the KAZA Secretariat.
3. Permission from Ministry of Works and Transport to overfly State Owned Aerodromes at Low-Level.
4. A detailed map of the area to be flown, with coordinates, and a full routing with the flight dates must be provided.
5. Aircraft documents:
    a. Current certificate of airworthiness,
    b. Current release to service,
    c. Current certificate of registration,
    d. Current aircraft certificate of insurance,
    e. Current radio licence,
    f. Current AOC/AWOC.
6. Crew documents:
    a. Current licences,
    b. Current medicals,
    c. Current Passports.

Zambia

1. Cover letter of request from the Air Operators Certificate (AOC) holder, stating proposed dates and areas of operation, aircraft type and registration name(s) of pilot(s).
2. Clearance from the Zambian Airforce.
3. Letter of Support from the Department of National Parks and Wildlife
4. Letter of Support from the KAZA Secretariat.
5. Aircraft documents:
    a. Current certificate of airworthiness,
    b. Current release to service,

   c. Current certificate of registration,
   d. Current aircraft certificate of insurance,
   e. Current radio licence,
   f. Current AOC.
6. Crew documents:
   a. Current licences,
   b. Current medicals,
   c. Current Passports.

A portion of the Kafue superstratum lies within the Mumbwa Prohibited Area (P4) and special permission was sought to survey within this zone. It is also customary in Zambia for such permits to be issued with the provision that both Civil Aviation Authority and Zambian Airforce representatives be physically present during the survey. These representatives may also accompany crew on survey flights.

Zimbabwe

1. Letter of endorsement from Zimbabwe Parks and Wildlife Management Authority
2. Letter of Support from the KAZA Secretariat.
3. Approval from Zimbabwe Defence Forces – approval was sought by ZPWMA and then issued to CAA.
4. Letter of approval from Zimbabwe Parks and Wildlife Management Authority to utilise the airstrips located in National Parks and Wildlife Management areas.
5. Complete Flight Permit Application Form (CA Form 50)
6. Map outlining full routing that the aircraft will be flying (with coordinates)
7. The time frame in which the flights will be conducted, including a detailed flight schedule with operational bases.
8. Entry and exit routes (FIR boundary crossings)
9. Full names & designations of all persons on board
10. Declaration that flights are non-profit (they may request Non-Profit Certificates)
11. Map outlining full routing that the aircraft will be flying (with coordinates
12. Aircraft documentation
    a. Current certificate of airworthiness
    b. Current release to service
    c. Current certificate of registration
    d. Current aircraft certificate of insurance
    e. Current radio licence
    f. Special permit to fly (if applicable),
13. Crew Documents:
    a. Current licences
    b. Current medicals
    c. Current Passports

Appendix 5: Reconnaissance flights

Reconnaissance flights, or "recce" flights as they are colloquially known, are informal, low-altitude aerial surveys, designed to identify and gather information about elephant populations. The flight path is not predetermined but often follows areas where elephants are more likely to be found, such as near water sources or riverine vegetation, especially during the dry season. The data collected can be used to aid stratification of a survey area and, without a formal survey, provides a minimum population estimate. During the KAZA Elephant Survey, three such flights were conducted, as documented in this report. The maps below illustrate the flight paths and locations of elephants observed.

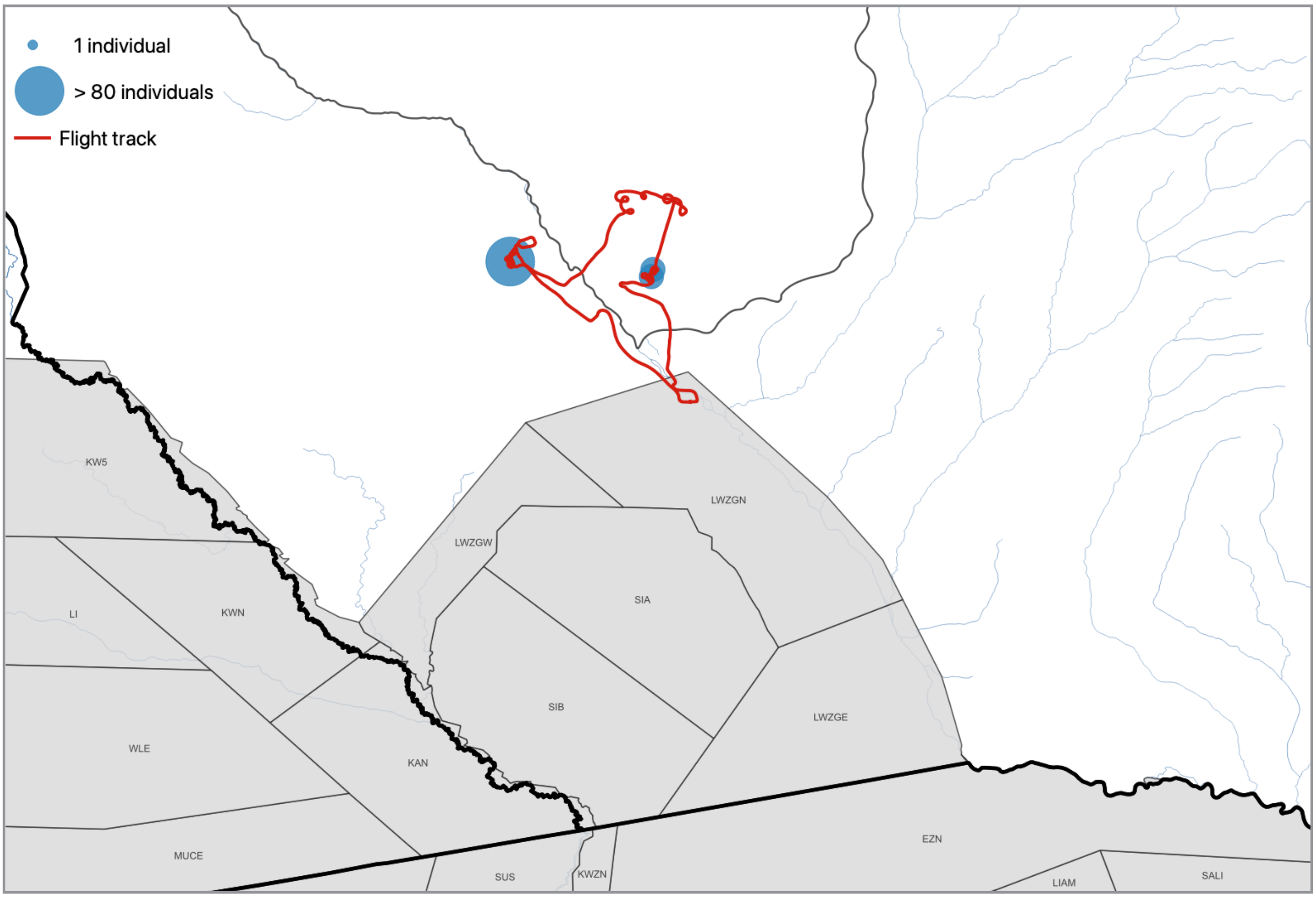


Figure A5.1: Map of recce flight track and elephant observations north of the Sioma superstratum in Zambia.

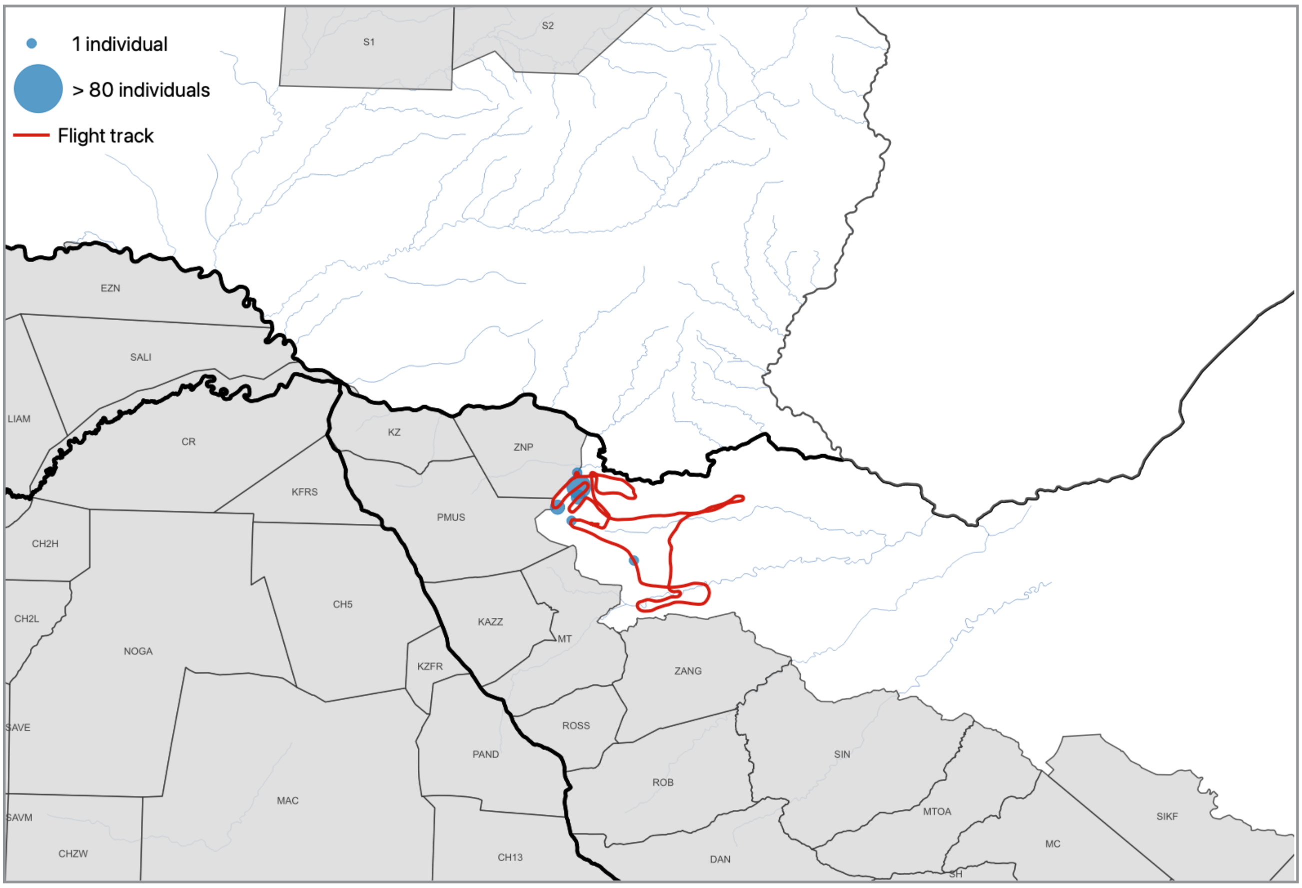


Figure A5.2: Map of recce flight track and elephant observations in the Fuller Forest area, east of the North West Matabeleland superstratum in Zimbabwe.

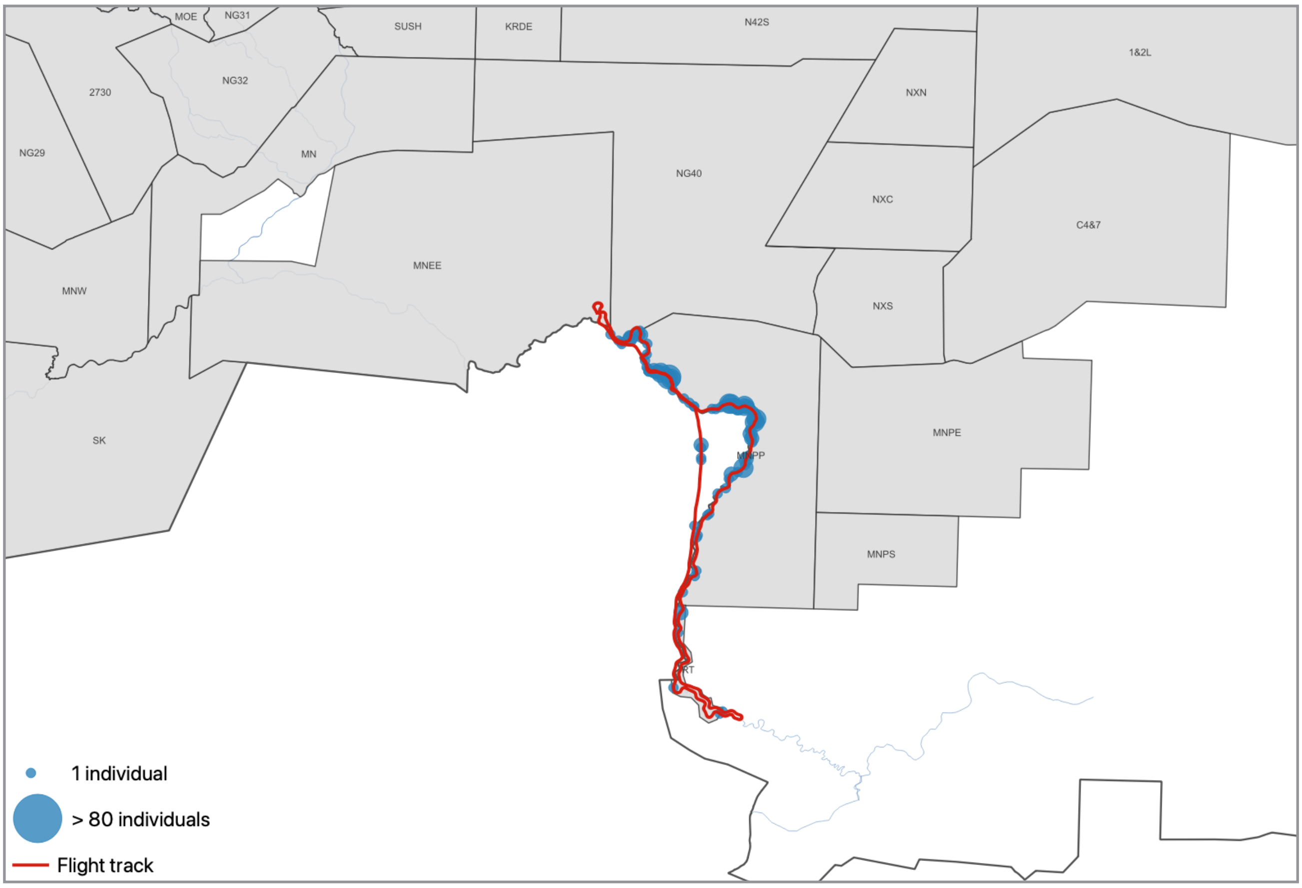


Figure A5.3: Map of recce flight track and elephant observations along the Boteti River southwards toward Rakops in Botswana.

Appendix 6: Detailed information on the efforts made by each crew in the sampling work.

Table A6.1: Summary of the work conducted by the different crews.

Crew	Aircraft	Team	No of strata	No of flights	Survey period	Start date	End date	Survey days	Flying days	Non-fly days	Non-fly freq.
C01	V5IIM	BushSkies	48	45	56	2022/08/30	2022/10/24	54	38	16	2.60
C02	V5LJB	BushSkies	45	41	51	2022/09/04	2022/10/24	49	31	18	1.72
C03	V5WOT	BushSkies	33	25	29	2022/09/03	2022/10/01	29	21	8	2.62
C04	V5WOT	BushSkies	15	17	23	2022/10/02	2022/10/24	21	15	6	2.50
C05	9JCMA	Flying Mission Zambia	20	21	28	2022/08/26	2022/09/22	28	21	7	3.00
C06	9JCMA	Flying Mission Zambia	1	1	1	2022/10/28	2022/10/28	1	1	0	-
C07	9JMFZ	Flying Mission Zambia	20	28	47	2022/08/27	2022/10/12	37	28	9	3.11
C08	ZYYB	BushSkies	24	16	19	2022/08/22	2022/09/09	19	16	3	5.33
C09	ZYVY	BushSkies	2	2	2	2022/08/23	2022/08/24	2	2	0	-

This table provides for each crew: the aircraft registration, the contractor, the number of surveyed strata and flights, the survey period and the corresponding start and end dates, the number of survey days, the number of flying days, the number of days spent not flying and its frequency (e.g., on average, crew C01 had one non-fly day after 2.6 flying days). All days spent on the ground were not rest days as they were often spent moving the camp from one survey base to another. A forced stop of the survey, for reasons of permit acquisition or strata synchronisation, explains the difference in survey period and survey days. This table includes the red lechwe count executed by crew C05.

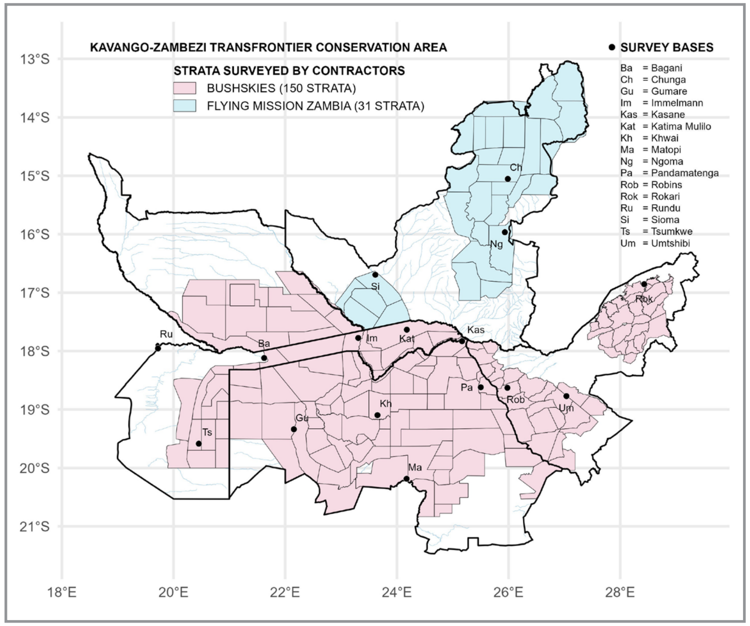


Figure A6.1: Map showing the allocation of strata between the two contractors.

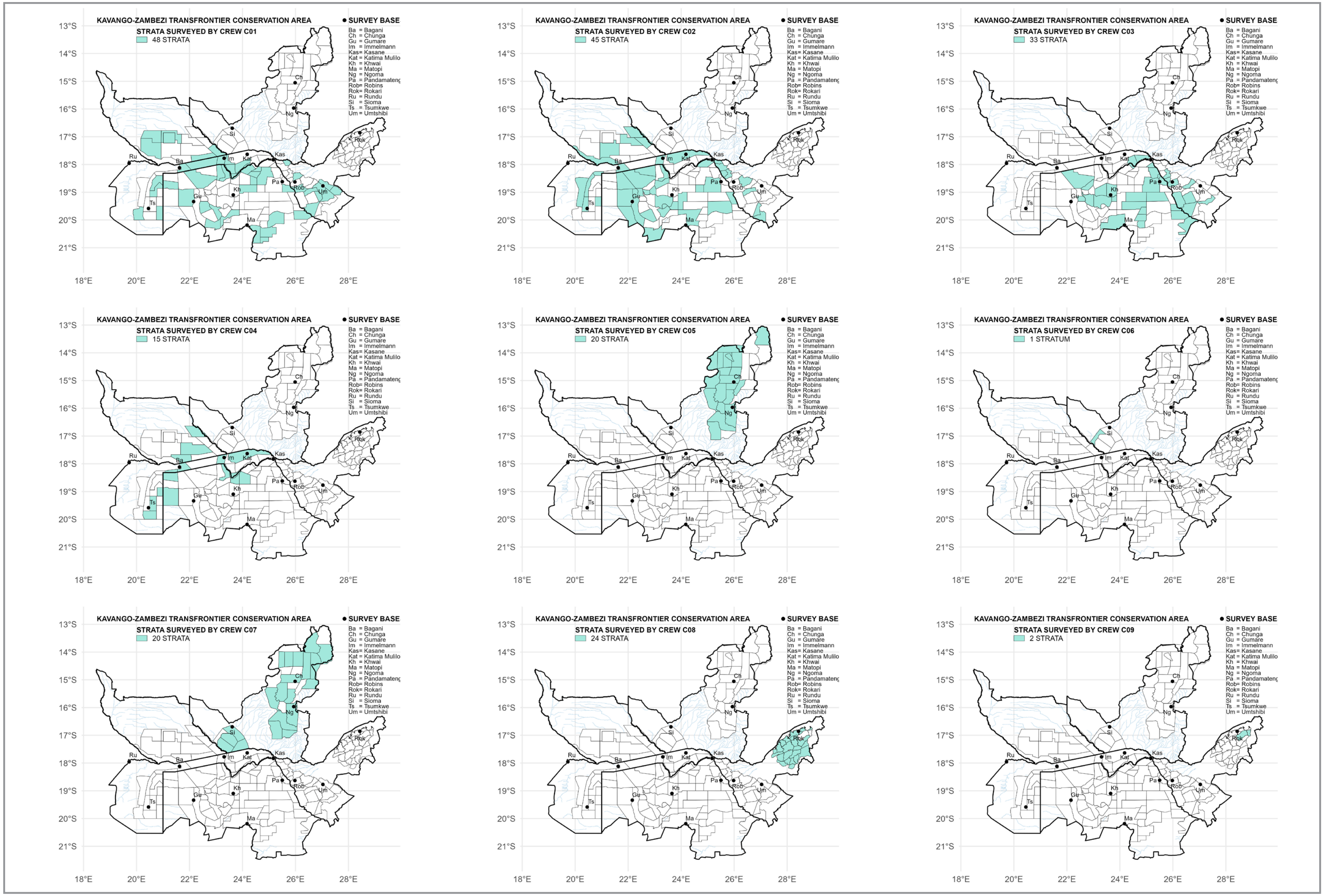


Figure A6.2: Series of maps showing the allocation of strata between the nine crews.

Appendix 7: Crew calendar

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C01	V5IIM	BushSkies	2022/08/30	survey is ongoing	KES2022_V5IIM20220830B	North-West Matabeleland	SIKF
C01	V5IIM	BushSkies	2022/08/31	survey is ongoing	KES2022_V5IIM20220831A – KES2022_V5IIM20220831B	North-West Matabeleland	NGAM
C01	V5IIM	BushSkies	2022/09/01	survey is ongoing	KES2022_V5IIM20220901A – KES2022_V5IIM20220901B	North-West Matabeleland	MC – CENA
C01	V5IIM	BushSkies	2022/09/02	survey is ongoing	KES2022_V5IIM20220902A – KES2022_V5IIM20220902B	North-West Matabeleland	NGFR – MC
C01	V5IIM	BushSkies	2022/09/03	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/04	survey is ongoing	KES2022_V5IIM20220904A	North-West Matabeleland	SH
C01	V5IIM	BushSkies	2022/09/05	survey is ongoing	KES2022_V5IIM20220905A	North-West Matabeleland	DZI
C01	V5IIM	BushSkies	2022/09/06	survey is ongoing	KES2022_V5IIM20220906A	North-West Matabeleland	DAN
C01	V5IIM	BushSkies	2022/09/07	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/08	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/09	survey is ongoing	KES2022_V5IIM20220909A	North-West Matabeleland	ZANG – ZNP
C01	V5IIM	BushSkies	2022/09/10	survey is ongoing	KES2022_V5IIM20220910A	Northern Botswana	NOGA
C01	V5IIM	BushSkies	2022/09/11	survey is ongoing	KES2022_V5IIM20220911A	Northern Botswana	CH13
C01	V5IIM	BushSkies	2022/09/12	survey is ongoing	KES2022_V5IIM20220912A	Northern Botswana	NGWS
C01	V5IIM	BushSkies	2022/09/13	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/14	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/15	survey is ongoing	KES2022_V5IIM20220915A	Northern Botswana	C4&7
C01	V5IIM	BushSkies	2022/09/16	survey is ongoing	KES2022_V5IIM20220916A	Northern Botswana	MNPE – MNPS
C01	V5IIM	BushSkies	2022/09/17	survey is ongoing	KES2022_V5IIM20220917A	Northern Botswana	MNPP
C01	V5IIM	BushSkies	2022/09/18	survey is ongoing	KES2022_V5IIM20220918A	Northern Botswana	MN
C01	V5IIM	BushSkies	2022/09/19	survey is ongoing	KES2022_V5IIM20220919A	Northern Botswana	MNW
C01	V5IIM	BushSkies	2022/09/20	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/21	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/22	survey is ongoing	KES2022_V5IIM20220922A – KES2022_V5IIM20220922B	Northern Botswana	2730 – N3NE
C01	V5IIM	BushSkies	2022/09/23	survey is ongoing	KES2022_V5IIM20220923A	Northern Botswana	NG11
C01	V5IIM	BushSkies	2022/09/24	survey is ongoing	KES2022_V5IIM20220924A	Northern Botswana	NG26
C01	V5IIM	BushSkies	2022/09/25	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/26	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/27	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/28	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/29	survey is ongoing			
C01	V5IIM	BushSkies	2022/09/30	survey is ongoing	KES2022_V5IIM20220930A	Northern Botswana	SAVE – SAVM
C01	V5IIM	BushSkies	2022/10/01	survey is ongoing	KES2022_V5IIM20221001A	Northern Botswana	CH2H – CH2L

C01	V5IIM	BushSkies	2022/10/02	survey is ongoing	KES2022_V5IIM20221002A	Kavango Zambezi	KWZN – ZASW
C01	V5IIM	BushSkies	2022/10/03	survey is ongoing	KES2022_V5IIM20221003B	Northern Botswana	N14L
C01	V5IIM	BushSkies	2022/10/04	survey is ongoing	KES2022_V5IIM20221004A – KES2022_V5IIM20221004B	Kavango Zambezi – Northern Botswana	MS – CH1
C01	V5IIM	BushSkies	2022/10/05	survey is ongoing			
C01	V5IIM	BushSkies	2022/10/06	survey is ongoing	KES2022_V5IIM20221006A	Northern Botswana	14H
C01	V5IIM	BushSkies	2022/10/07	survey is ongoing	KES2022_V5IIM20221007A	Kavango Zambezi	KWZ
C01	V5IIM	BushSkies	2022/10/08	survey is ongoing	KES2022_V5IIM20221008A	Kavango Zambezi	SUS
C01	V5IIM	BushSkies	2022/10/09	survey is ongoing	KES2022_V5IIM20221009A	Kavango Zambezi	BWA
C01	V5IIM	BushSkies	2022/10/10	survey is ongoing	KES2022_V5IIM20221010A – KES2022_V5IIM20221010B	Kavango Zambezi – Northern Botswana	BUF – N1SW
C01	V5IIM	BushSkies	2022/10/11	survey is ongoing			
C01	V5IIM	BushSkies	2022/10/12	survey is ongoing			
C01	V5IIM	BushSkies	2022/10/13	survey is ongoing	KES2022_V5IIM20221013A – KES2022_V5IIM20221013B	Khaudum Nyae-Nyae	KN – T1
C01	V5IIM	BushSkies	2022/10/14	survey is ongoing	KES2022_V5IIM20221014A	Khaudum Nyae-Nyae	TS3
C01	V5IIM	BushSkies	2022/10/15	survey is ongoing	KES2022_V5IIM20221015A	Khaudum Nyae-Nyae	KC
C01	V5IIM	BushSkies	2022/10/16	survey on hold			
C01	V5IIM	BushSkies	2022/10/17	survey on hold			
C01	V5IIM	BushSkies	2022/10/18	survey is ongoing	KES2022_V5IIM20221018A	Luengue-Luiana	KAN
C01	V5IIM	BushSkies	2022/10/19	survey is ongoing	KES2022_V5IIM20221019A	Luengue-Luiana	L10W
C01	V5IIM	BushSkies	2022/10/20	survey is ongoing	KES2022_V5IIM20221020A	Luengue-Luiana	WLW
C01	V5IIM	BushSkies	2022/10/21	survey is ongoing	KES2022_V5IIM20221021A	Luengue-Luiana	LIK
C01	V5IIM	BushSkies	2022/10/22	survey is ongoing	KES2022_V5IIM20221022A	Luengue-Luiana	L10E
C01	V5IIM	BushSkies	2022/10/23	survey is ongoing	KES2022_V5IIM20221023A	Luengue-Luiana	MUCE

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C02	V5LJB	BushSkies	2022/09/04	survey is ongoing	KES2022_V5LJB20220904A	North-West Matabeleland	MAIT – TSHE
C02	V5LJB	BushSkies	2022/09/05	survey is ongoing	KES2022_V5LJB20220905A	North-West Matabeleland	SH
C02	V5LJB	BushSkies	2022/09/06	survey is ongoing	KES2022_V5LJB20220906A	North-West Matabeleland	SIN
C02	V5LJB	BushSkies	2022/09/07	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/08	survey is ongoing	KES2022_V5LJB20220908A	North-West Matabeleland	MT – KAZZ
C02	V5LJB	BushSkies	2022/09/09	survey is ongoing	KES2022_V5LJB20220909A	North-West Matabeleland	KZ – PMUS
C02	V5LJB	BushSkies	2022/09/10	survey is ongoing	KES2022_V5LJB20220910A – KES2022_V5LJB20220910B	Northern Botswana	MAC – CT3

C02	V5LJB	BushSkies	2022/09/11	survey is ongoing	KES2022_V5LJB20220911A – KES2022_V5LJB20220911B	Northern Botswana	1&2L – CHZW
C02	V5LJB	BushSkies	2022/09/12	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/13	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/14	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/15	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/16	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/17	survey is ongoing	KES2022_V5LJB20220917A	Northern Botswana	NG40
C02	V5LJB	BushSkies	2022/09/18	survey is ongoing	KES2022_V5LJB20220918A	Northern Botswana	SK
C02	V5LJB	BushSkies	2022/09/19	survey is ongoing	KES2022_V5LJB20220919A – KES2022_V5LJB20220919B	Northern Botswana	WOKS
C02	V5LJB	BushSkies	2022/09/20	survey is ongoing	KES2022_V5LJB20220920A	Northern Botswana	WONE
C02	V5LJB	BushSkies	2022/09/21	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/22	survey is ongoing	KES2022_V5LJB20220922A – KES2022_V5LJB20220922B	Northern Botswana	N3NE – N3SE
C02	V5LJB	BushSkies	2022/09/23	survey is ongoing	KES2022_V5LJB20220923A – KES2022_V5LJB20220923B	Northern Botswana	NG23 – NG24 – NG11
C02	V5LJB	BushSkies	2022/09/24	survey is ongoing	KES2022_V5LJB20220924A – KES2022_V5LJB20220924B	Northern Botswana	NG22 – NG29
C02	V5LJB	BushSkies	2022/09/25	survey is ongoing	KES2022_V5LJB20220925A – KES2022_V5LJB20220925B	Northern Botswana	MOE
C02	V5LJB	BushSkies	2022/09/26	survey is ongoing	KES2022_V5LJB20220926A – KES2022_V5LJB20220926B	Northern Botswana	NG16 – SUSH
C02	V5LJB	BushSkies	2022/09/27	survey is ongoing	KES2022_V5LJB20220927A	Northern Botswana	KRDE
C02	V5LJB	BushSkies	2022/09/28	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/29	survey is ongoing			
C02	V5LJB	BushSkies	2022/09/30	survey is ongoing	KES2022_V5LJB20220930A	Northern Botswana	NG31 – NG32
C02	V5LJB	BushSkies	2022/10/01	survey is ongoing	KES2022_V5LJB20221001A	Northern Botswana	CR
C02	V5LJB	BushSkies	2022/10/02	survey is ongoing	KES2022_V5LJB20221002A	Kavango Zambezi	EZN
C02	V5LJB	BushSkies	2022/10/03	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/04	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/05	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/06	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/07	survey is ongoing	KES2022_V5LJB20221007A	Northern Botswana	14H
C02	V5LJB	BushSkies	2022/10/08	survey is ongoing	KES2022_V5LJB20221008A	Kavango Zambezi	SUS
C02	V5LJB	BushSkies	2022/10/09	survey is ongoing	KES2022_V5LJB20221009A	Northern Botswana	NG13
C02	V5LJB	BushSkies	2022/10/10	survey is ongoing	KES2022_V5LJB20221010A	Kavango Zambezi	BUF
C02	V5LJB	BushSkies	2022/10/11	survey is ongoing	KES2022_V5LJB20221011A	Khaudum Nyae-Nyae	KL1 – KL2
C02	V5LJB	BushSkies	2022/10/12	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/13	survey is ongoing	KES2022_V5LJB20221013A – KES2022_V5LJB20221013B	Khaudum Nyae-Nyae	L1 – TS1
C02	V5LJB	BushSkies	2022/10/14	survey is ongoing	KES2022_V5LJB20221014A	Khaudum Nyae-Nyae	TS6
C02	V5LJB	BushSkies	2022/10/15	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/16	survey on hold			

C02	V5LJB	BushSkies	2022/10/17	survey on hold			
C02	V5LJB	BushSkies	2022/10/18	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/19	survey is ongoing			
C02	V5LJB	BushSkies	2022/10/20	survey is ongoing	KES2022_V5LJB20221020B	Luengue-Luiana	CUON
C02	V5LJB	BushSkies	2022/10/21	survey is ongoing	KES2022_V5LJB20221021A – KES2022_V5LJB20221021B	Luengue-Luiana	CUON
C02	V5LJB	BushSkies	2022/10/22	survey is ongoing	KES2022_V5LJB20221022A	Luengue-Luiana	WLC
C02	V5LJB	BushSkies	2022/10/23	survey is ongoing	KES2022_V5LJB20221023A	Luengue-Luiana	LI
C02	V5LJB	BushSkies	2022/10/24	survey is ongoing	KES2022_V5LJB20221024A	Luengue-Luiana	KW5 – KWN

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C03	V5WOT	BushSkies	2022/09/03	survey is ongoing	KES2022_V5WOT20220903A – KES2022_V5WOT20220903B	North-West Matabeleland	CENB – TSHN
C03	V5WOT	BushSkies	2022/09/04	survey is ongoing	KES2022_V5WOT20220904A	North-West Matabeleland	MTOA
C03	V5WOT	BushSkies	2022/09/05	survey is ongoing	KES2022_V5WOT20220905A	North-West Matabeleland	DZI
C03	V5WOT	BushSkies	2022/09/06	survey is ongoing	KES2022_V5WOT20220906A	North-West Matabeleland	SHAK
C03	V5WOT	BushSkies	2022/09/07	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/08	survey is ongoing	KES2022_V5WOT20220908A	North-West Matabeleland	ROB – ROSS
C03	V5WOT	BushSkies	2022/09/09	survey is ongoing	KES2022_V5WOT20220909A	North-West Matabeleland	MT
C03	V5WOT	BushSkies	2022/09/10	survey is ongoing	KES2022_V5WOT20220910A – KES2022_V5WOT20220910B	Northern Botswana	CH5 – KFRS – KZFR – PAND – MAC
C03	V5WOT	BushSkies	2022/09/11	survey is ongoing	KES2022_V5WOT20220911A	Northern Botswana	1&2H
C03	V5WOT	BushSkies	2022/09/12	survey is ongoing	KES2022_V5WOT20220912A	Northern Botswana	NGWS
C03	V5WOT	BushSkies	2022/09/13	survey is ongoing	KES2022_V5WOT20220913A	Northern Botswana	NGWN
C03	V5WOT	BushSkies	2022/09/14	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/15	survey is ongoing	KES2022_V5WOT20220915A	Northern Botswana	NATA
C03	V5WOT	BushSkies	2022/09/16	survey is ongoing	KES2022_V5WOT20220916A	Northern Botswana	NXC – NXN – NXS
C03	V5WOT	BushSkies	2022/09/17	survey is ongoing	KES2022_V5WOT20220917A	Northern Botswana	MNEE
C03	V5WOT	BushSkies	2022/09/18	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/19	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/20	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/21	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/22	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/23	survey is ongoing	KES2022_V5WOT20220923A – KES2022_V5WOT20220923B	Northern Botswana	NG25 – NG11
C03	V5WOT	BushSkies	2022/09/24	survey is ongoing	KES2022_V5WOT20220924A	Northern Botswana	NG12
C03	V5WOT	BushSkies	2022/09/25	survey is ongoing	KES2022_V5WOT20220925A – KES2022_V5WOT20220925B	Northern Botswana	MOW – MOE
C03	V5WOT	BushSkies	2022/09/26	survey is ongoing	KES2022_V5WOT20220926A	Northern Botswana	1819 – MOTK
C03	V5WOT	BushSkies	2022/09/27	survey is ongoing	KES2022_V5WOT20220927A	Northern Botswana	NG20

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C03	V5WOT	BushSkies	2022/09/28	survey is ongoing			
C03	V5WOT	BushSkies	2022/09/29	survey is ongoing	KES2022_V5WOT20220929A	Northern Botswana	N42S
C03	V5WOT	BushSkies	2022/09/30	survey is ongoing	KES2022_V5WOT20220930A	Northern Botswana	N41L
C03	V5WOT	BushSkies	2022/10/01	survey is ongoing	KES2022_V5WOT20221001A	Kavango Zambezi	SALI – LIAM

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C04	V5WOT	BushSkies	2022/10/02	survey is ongoing	KES2022_V5WOT20221002A	Kavango Zambezi	EZN
C04	V5WOT	BushSkies	2022/10/03	survey is ongoing	KES2022_V5WOT20221003B	Northern Botswana	NG15
C04	V5WOT	BushSkies	2022/10/04	survey is ongoing	KES2022_V5WOT20221004A – KES2022_V5WOT20221004B	Northern Botswana – Kavango Zambezi	SAVN – MS
C04	V5WOT	BushSkies	2022/10/05	survey is ongoing			
C04	V5WOT	BushSkies	2022/10/06	survey is ongoing	KES2022_V5WOT20221006A	Northern Botswana	14H
C04	V5WOT	BushSkies	2022/10/07	survey is ongoing	KES2022_V5WOT20221007A	Northern Botswana	14H
C04	V5WOT	BushSkies	2022/10/08	survey is ongoing	KES2022_V5WOT20221008A	Kavango Zambezi	SUS
C04	V5WOT	BushSkies	2022/10/09	survey is ongoing	KES2022_V5WOT20221009A	Northern Botswana	NG1
C04	V5WOT	BushSkies	2022/10/10	survey is ongoing	KES2022_V5WOT20221010A	Kavango Zambezi	BUF
C04	V5WOT	BushSkies	2022/10/11	survey is ongoing	KES2022_V5WOT20221011A	Northern Botswana	N3NW
C04	V5WOT	BushSkies	2022/10/12	survey is ongoing			
C04	V5WOT	BushSkies	2022/10/13	survey is ongoing	KES2022_V5WOT20221013A – KES2022_V5WOT20221013B	Khaudum Nyae-Nyae	KS – TS7
C04	V5WOT	BushSkies	2022/10/14	survey is ongoing			
C04	V5WOT	BushSkies	2022/10/15	survey is ongoing	KES2022_V5WOT20221015A	Khaudum Nyae-Nyae	TS2
C04	V5WOT	BushSkies	2022/10/16	survey on hold			
C04	V5WOT	BushSkies	2022/10/17	survey on hold			
C04	V5WOT	BushSkies	2022/10/18	survey is ongoing			
C04	V5WOT	BushSkies	2022/10/19	survey is ongoing			
C04	V5WOT	BushSkies	2022/10/20	survey is ongoing			
C04	V5WOT	BushSkies	2022/10/21	survey is ongoing	KES2022_V5WOT20221021B	Luengue-Luiana	WLE
C04	V5WOT	BushSkies	2022/10/22	survey is ongoing	KES2022_V5WOT20221022A	Luengue-Luiana	MUCW
C04	V5WOT	BushSkies	2022/10/23	survey is ongoing	KES2022_V5WOT20221023A	Luengue-Luiana	WLE
C04	V5WOT	BushSkies	2022/10/24	survey is ongoing	KES2022_V5WOT20221024A	Luengue-Luiana	KW5

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C05	9JCMA	Flying Mission Zambia	2022/08/26	survey is ongoing	KES2022_9JCMA20220826A	Kafue	K
C05	9JCMA	Flying Mission Zambia	2022/08/27	survey is ongoing	KES2022_9JCMA20220827A	Kafue	A2
C05	9JCMA	Flying Mission Zambia	2022/08/28	survey is ongoing			
C05	9JCMA	Flying Mission Zambia	2022/08/29	survey is ongoing	KES2022_9JCMA20220829A	Kafue	A1
C05	9JCMA	Flying Mission Zambia	2022/08/30	survey is ongoing	KES2022_9JCMA20220830A	Kafue	Q1
C05	9JCMA	Flying Mission Zambia	2022/08/31	survey is ongoing	KES2022_9JCMA20220831A	Kafue	J2

C05	9JCMA	Flying Mission Zambia	2022/09/01	survey is ongoing	KES2022_9JCMA20220901A	Kafue	A3
C05	9JCMA	Flying Mission Zambia	2022/09/02	survey is ongoing			
C05	9JCMA	Flying Mission Zambia	2022/09/03	survey is ongoing	KES2022_9JCMA20220903A	Kafue	D
C05	9JCMA	Flying Mission Zambia	2022/09/04	survey is ongoing	KES2022_9JCMA20220904A	Kafue	L2
C05	9JCMA	Flying Mission Zambia	2022/09/05	survey is ongoing	KES2022_9JCMA20220905A	Kafue	C3
C05	9JCMA	Flying Mission Zambia	2022/09/06	survey is ongoing	KES2022_9JCMA20220906A	Kafue	G
C05	9JCMA	Flying Mission Zambia	2022/09/07	survey is ongoing			
C05	9JCMA	Flying Mission Zambia	2022/09/08	survey is ongoing	KES2022_9JCMA20220908A	Kafue	C1
C05	9JCMA	Flying Mission Zambia	2022/09/09	survey is ongoing	KES2022_9JCMA20220909A	Kafue	LCW
C05	9JCMA	Flying Mission Zambia	2022/09/10	survey is ongoing	KES2022_9JCMA20220910A	Kafue	C2
C05	9JCMA	Flying Mission Zambia	2022/09/11	survey is ongoing			
C05	9JCMA	Flying Mission Zambia	2022/09/12	survey is ongoing	KES2022_9JCMA20220912A	Kafue	L
C05	9JCMA	Flying Mission Zambia	2022/09/13	survey is ongoing	KES2022_9JCMA20220913A	Kafue	L
C05	9JCMA	Flying Mission Zambia	2022/09/14	survey is ongoing			
C05	9JCMA	Flying Mission Zambia	2022/09/15	survey is ongoing	KES2022_9JCMA20220915A	Kafue	E
C05	9JCMA	Flying Mission Zambia	2022/09/16	survey is ongoing	KES2022_9JCMA20220916A	Kafue	F
C05	9JCMA	Flying Mission Zambia	2022/09/17	survey is ongoing			
C05	9JCMA	Flying Mission Zambia	2022/09/18	survey is ongoing	KES2022_9JCMA20220918A	Kafue	N
C05	9JCMA	Flying Mission Zambia	2022/09/19	survey is ongoing			
C05	9JCMA	Flying Mission Zambia	2022/09/20	survey is ongoing	KES2022_9JCMA20220920A	Kafue	M
C05	9JCMA	Flying Mission Zambia	2022/09/21	survey is ongoing	KES2022_9JCMA20220921A	Kafue	T
C05	9JCMA	Flying Mission Zambia	2022/09/22	survey is ongoing	KES2022_9JCMA20220922A	Kafue	S1

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C06	9JCMA	Flying Mission Zambia	2022/10/28	survey is ongoing	KES2022_9JCMA20221028A	Sioma	LWZGW

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C07	9JMFZ	Flying Mission Zambia	2022/08/27	survey is ongoing	KES2022_9JMFZ20220827A	Kafue	A2
C07	9JMFZ	Flying Mission Zambia	2022/08/28	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/08/29	survey is ongoing	KES2022_9JMFZ20220829A	Kafue	A1
C07	9JMFZ	Flying Mission Zambia	2022/08/30	survey is ongoing	KES2022_9JMFZ20220830A	Kafue	Q3
C07	9JMFZ	Flying Mission Zambia	2022/08/31	survey is ongoing	KES2022_9JMFZ20220831A	Kafue	Q2
C07	9JMFZ	Flying Mission Zambia	2022/09/01	survey is ongoing	KES2022_9JMFZ20220901A	Kafue	A3
C07	9JMFZ	Flying Mission Zambia	2022/09/02	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/09/03	survey is ongoing	KES2022_9JMFZ20220903A	Kafue	HE
C07	9JMFZ	Flying Mission Zambia	2022/09/04	survey is ongoing	KES2022_9JMFZ20220904A	Kafue	HE
C07	9JMFZ	Flying Mission Zambia	2022/09/05	survey is ongoing	KES2022_9JMFZ20220905A	Kafue	HW – HE
C07	9JMFZ	Flying Mission Zambia	2022/09/06	survey is ongoing	KES2022_9JMFZ20220906A	Kafue	HW
C07	9JMFZ	Flying Mission Zambia	2022/09/07	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/09/08	survey is ongoing	KES2022_9JMFZ20220908A	Kafue	HW
C07	9JMFZ	Flying Mission Zambia	2022/09/09	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/09/10	survey is ongoing	KES2022_9JMFZ20220910A	Kafue	C2
C07	9JMFZ	Flying Mission Zambia	2022/09/11	survey is ongoing	KES2022_9JMFZ20220911A	Kafue	C2
C07	9JMFZ	Flying Mission Zambia	2022/09/12	survey is ongoing	KES2022_9JMFZ20220912A	Kafue	G2
C07	9JMFZ	Flying Mission Zambia	2022/09/13	survey is ongoing	KES2022_9JMFZ20220913A	Kafue	L
C07	9JMFZ	Flying Mission Zambia	2022/09/14	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/09/15	survey is ongoing	KES2022_9JMFZ20220915A	Kafue	E
C07	9JMFZ	Flying Mission Zambia	2022/09/16	survey is ongoing	KES2022_9JMFZ20220916A	Kafue	F
C07	9JMFZ	Flying Mission Zambia	2022/09/17	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/09/18	survey is ongoing	KES2022_9JMFZ20220918A	Kafue	N
C07	9JMFZ	Flying Mission Zambia	2022/09/19	survey is ongoing	KES2022_9JMFZ20220919A	Kafue	N
C07	9JMFZ	Flying Mission Zambia	2022/09/20	survey is ongoing	KES2022_9JMFZ20220920A	Kafue	T
C07	9JMFZ	Flying Mission Zambia	2022/09/21	survey is ongoing	KES2022_9JMFZ20220921A	Kafue	T

C07	9JMFZ	Flying Mission Zambia	2022/09/22	survey is ongoing	KES2022_9JMFZ20220922A	Kafue	S2 – S1
C07	9JMFZ	Flying Mission Zambia	2022/09/23	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/09/24	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/09/25	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/09/26	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/09/27	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/09/28	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/09/29	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/09/30	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/10/01	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/10/02	survey on hold			
C07	9JMFZ	Flying Mission Zambia	2022/10/03	survey is ongoing	KES2022_9JMFZ20221003A	Sioma	LWZGN
C07	9JMFZ	Flying Mission Zambia	2022/10/04	survey is ongoing	KES2022_9JMFZ20221004A	Sioma	LWZGE
C07	9JMFZ	Flying Mission Zambia	2022/10/05	survey is ongoing	KES2022_9JMFZ20221005A	Sioma	LWZGN
C07	9JMFZ	Flying Mission Zambia	2022/10/06	survey is ongoing	KES2022_9JMFZ20221006A	Sioma	SIA
C07	9JMFZ	Flying Mission Zambia	2022/10/07	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/10/08	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/10/09	survey is ongoing			
C07	9JMFZ	Flying Mission Zambia	2022/10/10	survey is ongoing	KES2022_9JMFZ20221010A	Sioma	SIA
C07	9JMFZ	Flying Mission Zambia	2022/10/11	survey is ongoing	KES2022_9JMFZ20221011A	Sioma	SIB
C07	9JMFZ	Flying Mission Zambia	2022/10/12	survey is ongoing	KES2022_9JMFZ20221012A	Sioma	SIB

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C08	ZYYB	BushSkies	2022/08/22	survey is ongoing	KES2022_ZYYB20220822A	Sebungwe	CG
C08	ZYYB	BushSkies	2022/08/23	survey is ongoing	KES2022_ZYYB20220823A	Sebungwe	SG
C08	ZYYB	BushSkies	2022/08/24	survey is ongoing	KES2022_ZYYB20220824A	Sebungwe	RA
C08	ZYYB	BushSkies	2022/08/25	survey is ongoing			
C08	ZYYB	BushSkies	2022/08/26	survey is ongoing	KES2022_ZYYB20220826A	Sebungwe	BS
C08	ZYYB	BushSkies	2022/08/27	survey is ongoing	KES2022_ZYYB20220827A	Sebungwe	ZW
C08	ZYYB	BushSkies	2022/08/28	survey is ongoing	KES2022_ZYYB20220828A	Sebungwe	ZE
C08	ZYYB	BushSkies	2022/08/29	survey is ongoing	KES2022_ZYYB20220829A	Sebungwe	LU – SM
C08	ZYYB	BushSkies	2022/08/30	survey is ongoing			
C08	ZYYB	BushSkies	2022/08/31	survey is ongoing	KES2022_ZYYB20220831A	Sebungwe	SJ – SW
C08	ZYYB	BushSkies	2022/09/01	survey is ongoing	KES2022_ZYYB20220901A	Sebungwe	CW
C08	ZYYB	BushSkies	2022/09/02	survey is ongoing	KES2022_ZYYB20220902A	Sebungwe	CE – SE
C08	ZYYB	BushSkies	2022/09/03	survey is ongoing	KES2022_ZYYB20220903A	Sebungwe	MD – SB
C08	ZYYB	BushSkies	2022/09/04	survey is ongoing			
C08	ZYYB	BushSkies	2022/09/05	survey is ongoing	KES2022_ZYYB20220905A	Sebungwe	GG – ME – MW
C08	ZYYB	BushSkies	2022/09/06	survey is ongoing	KES2022_ZYYB20220906A	Sebungwe	MP – NG
C08	ZYYB	BushSkies	2022/09/07	survey is ongoing	KES2022_ZYYB20220907A	Sebungwe	SP
C08	ZYYB	BushSkies	2022/09/08	survey is ongoing	KES2022_ZYYB20220908A	Sebungwe	CN – CS
C08	ZYYB	BushSkies	2022/09/09	survey is ongoing	KES2022_ZYYB20220909A	Sebungwe	NN

Crew	Aircraft	Team	DATE	Status	Flight ID	Superstrata	Strata
C09	ZYVY	BushSkies	2022/08/23	survey is ongoing	KES2022_ZYVY20220823A	Sebungwe	MH
C09	ZYVY	BushSkies	2022/08/24	survey is ongoing	KES2022_ZYVY20220824A	Sebungwe	KH – MH

Appendix 8: Weekly progress of the sampling effort.

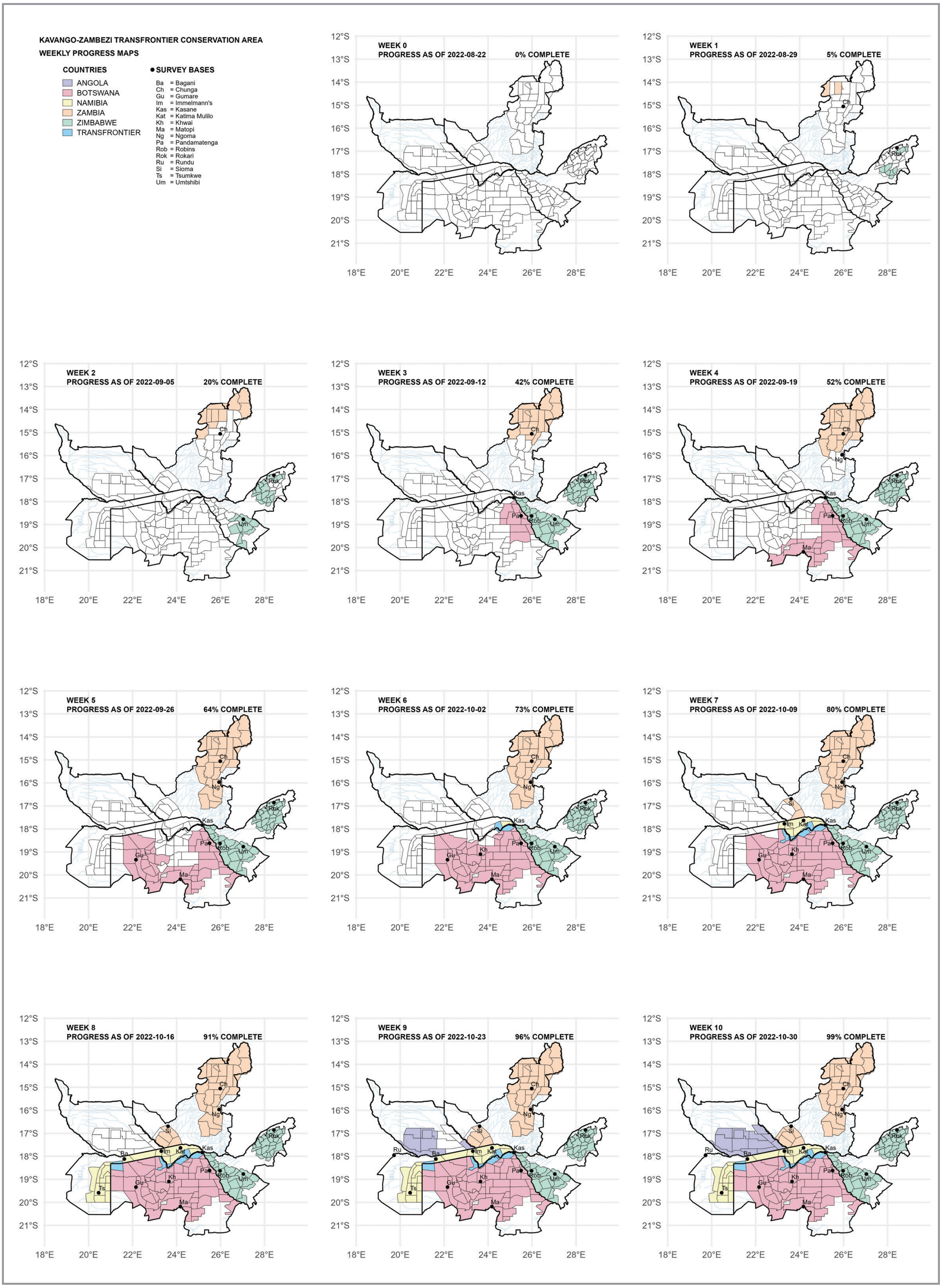


Figure A8.1: Overview of weekly progress of the sampling effort

Appendix 9: Equipment used for the survey

Table A9.1: Details of the equipment used by each crew

Item	Make	Model	Function
Laser Altimeter	Lightware	SF30/D	Measures height above ground level
Smartphone	Samsung	Galaxy A22	Displays and records laser data and records GPS track using the Flightlogger app
GPS	Garmin	Aera 660	Pilot navigation and records track
GPS	Garmin	GPSMAP 65S	Front Seat Recorder GPS to record waypoints and record track
Digital Voice Recorder	Sony	ICD-PX470	Records crew audio through intercom
Audio splitter cable	Nflightcam	Audio Recording Cable	Allows DVR to connect to aircraft intercom system
Digital camera	Canon	2000D	Digital camera to take photographs of wildlife observations
Camera lens	Canon	18-55mm	Camera lens
Remote release	Canon	RS-60E3	To remotely trigger the mounted cameras
Satellite communicator	Garmin	InReach Mini	Iridium satellite communicator for tracking and two-way messaging
Laptop	Dell	Latitude 3420	Laptop for data managers to capture store and analyse data
Suction cup mount	Panavise	809	Mount to attach cameras in the interior of the aircraft
Storage card	Sandisk	128Gb SD	SD memory card for Canon camera
Storage card	Integral	16Gb SD	Additional SD card for pilot GPS
Storage disk	Sandisk	1Tb SSD	Portable hard drive for in-field storage of survey data
Card Reader	Lexar	MULTI-CARD 3-IN-1	Multi-card reader to read memory cards
Universal mount	RAM	RAM-HOL-UN7BU	Universal phone mount to attach the smartphone
Rechargeable battery	GPB	LP-E10	Spare battery for Canon camera
Rechargeable battery	Powerex	AAA	Batteries for the handheld FSO GPS
Rechargeable battery	Powerex	AA	Batteries for the DVR
Battery charger	GPB	GPB-BM001	Spare generic charger for the camera batteries
Battery charger	Nitecore	Intellicharger i4	Charger for AAA and AA batteries

Table A9.2: Details of aircraft used for the survey

Registration	Designator	Make	Model	Seats
ZYVY	PA-18	Piper	SuperCub	2
V5WOT	C182	Cessna	Skylane	4
V5IIM	C182	Cessna	Skylane	4
V5LJB	C206	Cessna	Stationair	6
9JCMA	C206	Cessna	Stationair	6
9JMFZ	C206	Cessna	Stationair	6
ZYYB	C206	Cessna	Stationair	6

Notes on the equipment used:

1. Aircraft

Suitable high-wing aircraft were used in accordance with the CITES MIKE Aerial Survey Standards v3.0 (CITES Secretariat, 2020). An 8th aircraft, Cessna 182, was used by the coordinator in a liaison role to get to the field teams and to transport data back to the Operations Room, as well as to conduct two of the three reconnaissance flights.

2. Horizontal Navigation

The survey design was flown with the aid of an aviation grade Global Positioning System (GPS) (Garmin Aera 660). The planned transects were uploaded to the device daily. The pilots from Flying Mission Zambia (2 aircraft) preferred to use the SkyDemon app on iPad tablets for navigation.

3. Vertical Navigation

Height above ground was maintained with reference to the display of data on an Android smartphone using the Flightlogger application connected to a Lightware SF30/D laser range finder. The application recorded a log of height and GPS based ground speed at a 1 second frequency. The smartphone displaying the height data was mounted to the cockpit glareshield using a RAM mount.

4. Cameras

Cameras were securely mounted to the rear Perspex windows using the Panavise suction cup mounts on either side of the aircraft and calibrated to the observer's field of sight. Cameras were triggered by observers via remote cable release. In the case where MWS cameras were mounted inside the cockpit observers did not trigger photographs, instead the cameras were triggered by internal intervalometers at a 2 second frequency. The MWS project used Sony Alpha 7 iv cameras.

5. Audio recording

Using a Sony digital voice recorder and the Nflightcam splitter cable the intercom communications of the crew were recorded. This voice data was used to review and verify observations, where clarity was required in the written data sheet, and served as a backup dataset.

6. Observation waypoints

The Front Seat Observer recorded the position of observations using Garmin GPSMAP 65s handheld GPS units.

7. Satellite tracker and communications unit

Garmin InReach Mini devices with subscription to the Garmin Explore platform we carried on every flight. This ensured aircraft and crews could be tracked and communication maintained even in areas with no GSM coverage. Tracking and two-communication between field teams and the Operations Room was performed through integration with the EarthRanger platform.

8. Strip marker rods

Not mentioned in the table of equipment, since they were custom made for the project, are the strut mount brackets and rods used to delineate the search strips. The clamps were machined from aircraft grade aluminium to fit the exact strut profiles of the Cessna 182 and 206 with ported holes to accept the rigid carbon fibre rods made for the purpose. The system was produced to exacting engineering standards to ensure the rods are angled to be level and parallel in normal flight attitudes.

9. Flightlogger application

The Flightlogger app was designed by the team from Vulcan for the 2014 Great Elephant Census. Prior to this survey, in collaboration with the MWS team, a consulting programmer was engaged to update the application to function on a 7-inch smartphone display, rather than large tablets as in earlier versions, and to ensure functioning with later versions of the Android operating system and Lightware SF30/D laser.

Appendix 10: Personnel involved in the survey.

In the years leading up to the start of the KAZA Elephant Survey (2022), numerous actors were involved in the conception and planning of the project. The roles presented in this section are limited to those who were directly involved in the final phase of the project, and particularly in its implementation on the ground since the beginning of 2022.

Management

The survey management team consists of a partnership between the KAZA Secretariat and the governments of the five partner countries and WWF Namibia, the survey grant manager. The survey and the data collected remain the property of the partner states.

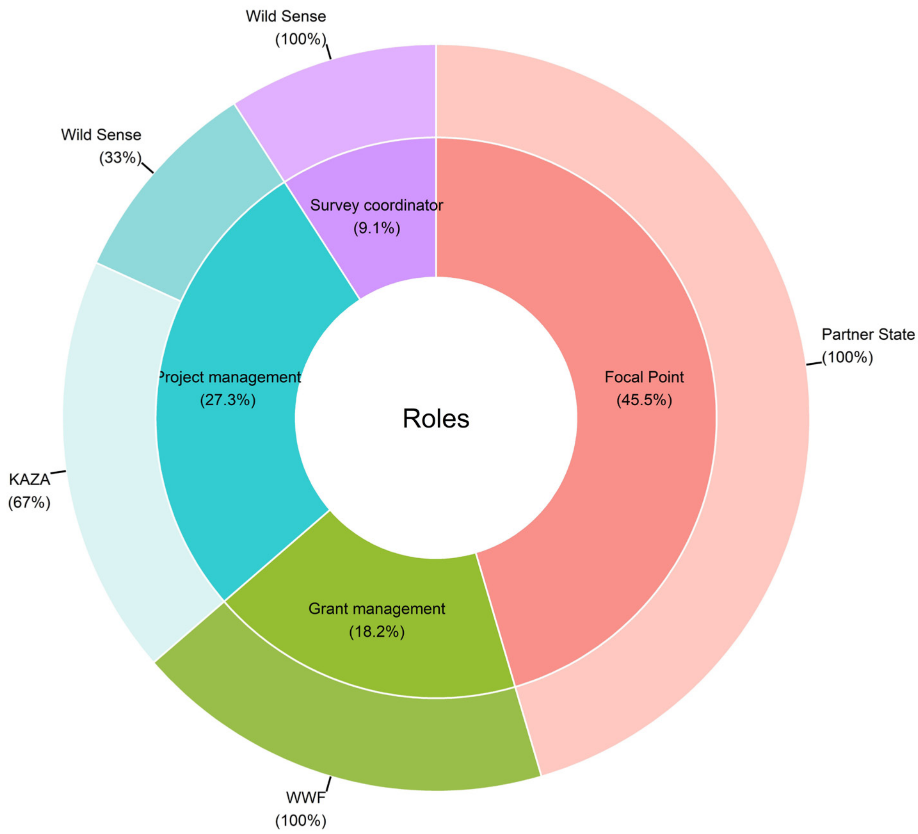


Figure A10.1: Management staff

Coordination

The conduct of the KAZA Elephant Survey (2022) required the mobilisation of many resources, human, material and financial, across several international borders, over a period of just over two months. The objectives and procedures for carrying out the survey had to be agreed upon, understood and applied by all. This synchronisation of everyone's efforts was made possible through coordination. This responsibility was entrusted to Wild Sense, a South African company that offers aviation services to the wildlife conservation industry, specialising in aerial game counts. Wild Sense established a coordination team whose duty was to facilitate communication and collaboration between all stakeholders, while ensuring unity of direction so that all aircrew members understood the nature of their role and responsibilities. The effective integration of these different functions allowed for the achievement of the common goal and an optimised use of resources.

Operations room

The coordination team set up and then relied throughout the survey on the operations room, whose daily operations were carried out by six data analysts.

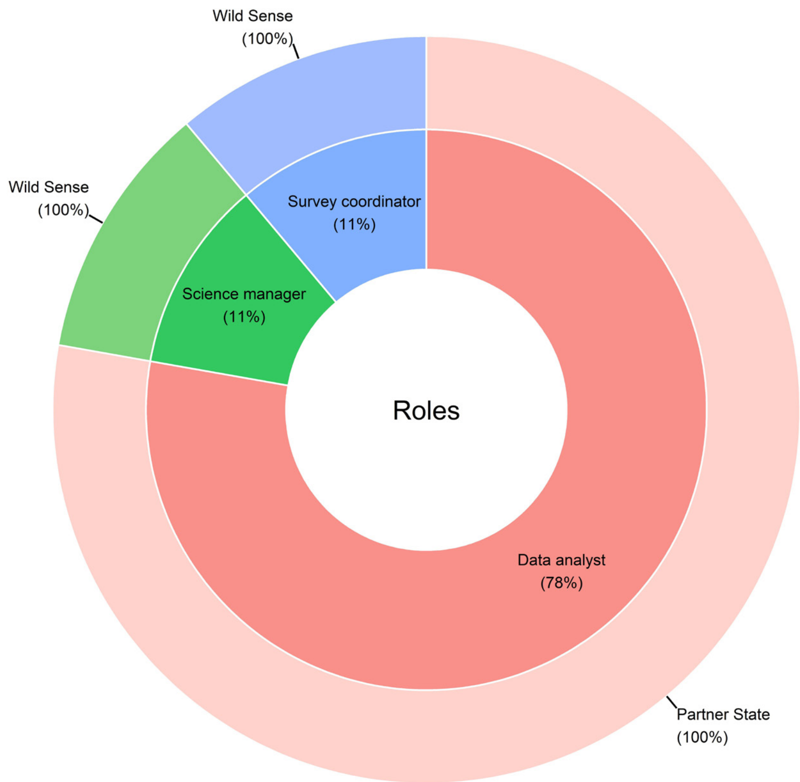


Figure A10.2: Data analysts

Crews

All crews were formed to fill four roles: pilot, front seat observer, rear seat observer and data manager. For many crews, pilots, front seat observers and data managers were rotated. However, for each of the nine crews that were mobilised for this survey, the aircraft and the associated rear seat observers never changed once the initial calibration had been carried out and validated. Most of the crews worked in collaboration with the consultants in charge of the Modernising Wildlife Surveys project (MWS), an initiative that took place simultaneously. Some data managers and front seat observers were given the responsibility of handling the MWS equipment and downloading thousands of images after each flight.

Pilot: All seven pilots selected for the KAZA Elephant Survey (2022) were all commercially licensed with good bush flying experience. Apart from one, all pilots had more than 1000 hours flying time, and all had demonstrated that they were comfortable and experienced in low-level flying and able to maintain the flight parameters as required for the survey, while ensuring the safety of the entire crew.

Front Seat Observer (FSO): All selected front seat observers were wildlife biologists and/or wildlife conservation professionals. They all had some experience of aerial surveys and flight survey procedures, and were able to:

- monitor compliance with the parameters required for the successful completion of the survey (height above ground, ground speed, flight plan) and advise correction in the event of significant deviation.

- supervise and interact with the observers seated at the back.
- take recordings (observations and positions) quickly and accurately on paper and in a GPS.

Rear Seat Observer (RSO): All rear seat observers but one had taken part in the Training and Evaluation Workshop held in Kasane from 20-26 July 2022, during which, the candidates nominated by the five KAZA partner states were trained, to ensure that their skills met minimum standards. The best performers were selected to take part in the KAZA Elephant Survey (2022). They all had some flying and aerial survey experience prior to their selection.

A more detailed presentation of the workshop and its selection process is provided in Appendix 1.

Data Manager: For each crew, one or more data managers were mobilised with the responsibility of downloading, transcribing, interpreting and archiving the data. This role, considered optional in some surveys, proved to be crucial for the smooth running of the KAZA Elephant Survey (2022), which was a prolonged, fast-paced undertaking in sometimes difficult and challenging field conditions. Although they did not go through a rigorous selection process, unlike the other crew members, the data managers identified for the survey were all comfortable using computer and technological tools and demonstrated scientific rigor. Apart from one crew, all data managers received, before the launch of the survey, an orientation concerning the tools, files, and procedures to be followed during the survey, a necessity for the standardisation of all datasets. In particular, the data managers then took in hand immediate flight data visualisation tools (scripts written in the R programming language) to assess pilot and observer performance.

Support staff: Each crew was supported by a ground support team responsible for a large part of the logistics once the crews were moving from one operational base to another. They include logisticians, drivers, and cooks. Add workshop, ops room, list of staff and crew composition appendices.

Figure A10.3: Data collectors

In the following tables the survey personnel are listed first in alphabetical order based on their role, and then in alphabetical order based on their last name.

Table A10.1: List of personnel involved in the management of the KAZA Elephant Survey (2022)

Name	Role	Occupation	Affiliation	Country
Prof. Edson Gandiwa	Focal Point	Director of scientific services	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
Twakundine Simpamba	Focal Point	Senior ecologist	Department of National Parks and Wildlife (DNPW)	Zambia
Malebogo Somolekae	Focal Point	Deputy director	Department of Wildlife and National Parks (DWNP)	Botswana
Dr. Kenneth Uiseb	Focal Point	Deputy director	Ministry of Environment, Forest and Tourism (MEFT)	Namibia
Fernando Verissimo	Focal Point	Chief of law enforcement	Luengue-Luiana National Park	Angola
Shereen Pieterse	Project management	Project administrator	WWF Namibia	Namibia
Dr. Russel Taylor	Project management	Transboundary conservation planning advisor	WWF Namibia	Zimbabwe
Netsai Bollman	Project management	Programme manager	KAZA Secretariat	Zimbabwe
Dr. Nyambe Nyambe	Project management	Executive director	KAZA Secretariat	Zambia
Darren Potgieter	Survey coordinator	Pilot, survey biologist and executive director	Wild Sense	South Africa

Table A10.2: List of contracted personnel involved in the coordination of the KAZA Elephant Survey (2022)

Name	Role	Affiliation	Country
Jason Frank	Project management assistant	Wild Sense	South Africa
Imogen Potgieter	Administration manager	Wild Sense	South Africa
Dylan Blew	Logistics manager	Wild Sense	South Africa
Dr. Elsa Bussière	Science and technology manager	Wild Sense	France
Darren Potgieter	Survey coordinator	Wild Sense	South Africa

Table A10.3: List of personnel in charge of field teams

Name	Role	Occupation	Affiliation	Country
Dr. Kevin Dunham	Survey biologist	Survey biologist	BushSkies	Zimbabwe
Dr. Deborah Gibson	Survey biologist	Survey biologist	BushSkies	Namibia
Twakundine Simpamba	Survey biologist	Senior ecologist	Department of National Parks and Wildlife (DNPW)	Zambia
Jaco Van der Westhuizen	Team manager	Owner, flight and ground operations manager	BushSkies	Namibia

Table A10.4: List of personnel involved in the logistical planning and execution of the KAZA Elephant Survey (2022)

Name	Role	Affiliation	Country
Efraim Tjirimuye	Assistant cook	BushSkies	Namibia
Stanley Tjirimuye	Cook	BushSkies	Namibia
Twakundine Simpamba	Survey biologist	Department of National Parks and Wildlife (DNPW)	Zambia
Sianga Mutendewa	Driver	Department of National Parks and Wildlife (DNPW)	Zambia
Frederick Bezuidenhout	Driver	BushSkies	Namibia
Sören Jensen	Logistics	BushSkies	Namibia
Dylan Blew	Logistics manager	Wild Sense	South Africa
Darren Potgieter	Survey coordinator	Wild Sense	South Africa
Jaco Van der Westhuizen	Team manager	BushSkies	Namibia

Table A10.10a: List of personnel involved in the collection of the KAZA Elephant Survey (2022) data

Name	Role	Occupation	Affiliation	Country	Crew	Side
Clive Chifunte	Data manager	Senior ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C05-C06-C07	
Christa D'Alton	Data manager	Conservationist	BushSkies	Namibia	C03-C04	
Novald Iiyambo	Data manager	Senior conservation scientist	Directorate of Wildlife and National Parks (DWNP)	Namibia	C02	
Kuzivakwashe Mawoyo	Data manager	Ecologist	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe	C01-C02-C03-C04	
Musonda Mwela	Data manager	GIS Specialist	Department of National Parks and Wildlife (DNPW)	Zambia	C05-C06-C07	
Debra Nachinga	Data manager	Ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C05-C06-C07	
Dr. Fay Robertson	Data manager	Ecologist	BushSkies	Zimbabwe	C08-C09	
Michelle Rodgers	Data manager	Ecologist	BushSkies	Namibia	C01	

Table A10.10b: List of personnel involved in the collection of the KAZA Elephant Survey (2022) data, continued.

Name	Role	Occupation	Affiliation	Country	Crew	Side
Twakundine Simpamba	Data manager	Senior ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C05-C06-C07	
Saferana Banda	Front seat observer	Ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C07	
Mathilde Brassine	Front seat observer	Biologist	BushSkies	Belgium	C01-C03	
Mwansa Chisanga	Front seat observer	Ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C04	
Dr. Kevin Dunham	Front seat observer	Ecologist	BushSkies	Zimbabwe	C08-C09	
Dr. Deborah Gibson	Front seat observer	Ecologist	BushSkies	Namibia	C01-C02-C03-C04	
Johannes Le Roux	Front seat observer	Conservation biologist	BushSkies	South Africa	C01-C02-C03-C04	
Howard Maimbo	Front seat observer	Senior ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C01-C05	
Gregory Nyaguse	Front seat observer	Senior ecologist	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe	C01-C02-C03-C04	
Darren Potgieter	Front seat observer	Pilot, survey biologist and executive director	Wild Sense	South Africa	C06	
Malebogo Somolekae	Front seat observer	Deputy director	Department of Wildlife and National Parks (DWNP)	Botswana	C01-C03	
Howard Frederick	MWS Consultant	Contracted survey expert	Wild Me	Australia		
Dr. Richard Lamprey	MWS Consultant	Contracted survey expert	Wild Me	England		
Timo Behr	Pilot – P08	Pilot	Flying Mission Zambia	Zambia	C05-C07	
Joel Bolthouse	Pilot – P04	Pilot	Flying Mission Zambia	Zambia	C05	
David Francis	Pilot – P02	Pilot	BushSkies	Namibia	C02	
Ian Lordanich	Pilot – P07	Pilot	Flying Mission Zambia	Zambia	C05-C07	
Raymond Paul	Pilot – P06	Pilot	BushSkies	Zimbabwe	C08	
Caroline Puzey	Pilot – P09	Pilot	BushSkies	Zimbabwe	C09	
Lukas Schmidt	Pilot – P05	Pilot	Flying Mission Zambia	Zambia	C07	
Jason Speichinger	Pilot – P10	Pilot	Flying Mission Zambia	Zambia	C06	
Johanco Steenkamp	Pilot – P01	Pilot	BushSkies	Namibia	C03-C04	
Jan Steyger	Pilot – P01	Pilot	BushSkies	Namibia	C01	

Table A10.10c: List of personnel involved in the collection of the KAZA Elephant Survey (2022) data, continued.

Name	Role	Occupation	Affiliation	Country	Crew	Side
Mwansa Chisanga	Rear seat observer	Ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C05	L
Ngoni Chitemamuswe	Rear seat observer	Assistant research officer, ornithologist	BushSkies	Zimbabwe	C03	R
Adrian Kaluka	Rear seat observer	Ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C07	R
Anety Milimo	Rear seat observer	Research technician	Department of National Parks and Wildlife (DNPW)	Zambia	C04-C05-C06	R
Ed Mordt	Rear seat observer	Pilot and Director	Executive Air	Zimbabwe	C09	
Ashley Mudungwe	Rear seat observer	Senior ecologist	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe	C01	R
Ezekiel Mungoni	Rear seat observer	Senior ranger	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe	C08	L
Fungai Muroki	Rear seat observer	Independent ecologist	BushSkies	Zimbabwe	C01	L
Debra Nachinga	Rear seat observer	Ecologist	Department of National Parks and Wildlife (DNPW)	Zambia	C06	L
Gregory Nyaguse	Rear seat observer	Senior ecologist	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe	C08	R
Gabriel Shatumbu	Rear seat observer	Pilot	Directorate of Wildlife and National Parks (DWNP)	Namibia	C02	L
Hans Swartbooi	Rear seat observer	Assistant ranger	Directorate of Wildlife and National Parks (DWNP)	Namibia	C03-C04	L
Talison Tembo	Rear seat observer	Wildlife police officer	Department of National Parks and Wildlife (DNPW)	Zambia	C07	L
Omphile Zweezwee	Rear seat observer	Wildlife officer	Department of Wildlife and National Parks (DWNP)	Botswana	C02	R
Moloki Lepodise	Stand-by rear seat observer	Senior wildlife ranger II	Department of Wildlife and National Parks (DWNP)	Botswana		
Phillip Molamu	Stand-by rear seat observer	Assistant wildlife warden	Department of Wildlife and National Parks (DWNP)	Botswana		

Table A10.11a: List of personnel in each of the nine crews.

Crew	Aircraft	Model	Role	Name	Affiliation	Country
C01	V5IIM	Cessna 182	Data manager	Kuzivakwashe Mawoyo	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C01	V5IIM	Cessna 182	Data manager	Michelle Rodgers	BushSkies	Namibia
C01	V5IIM	Cessna 182	Front seat observer	Mathilde Brassine	BushSkies	Belgium
C01	V5IIM	Cessna 182	Front seat observer	Deborah Gibson	BushSkies	Namibia
C01	V5IIM	Cessna 182	Front seat observer	Johannes Le Roux	BushSkies	South Africa
C01	V5IIM	Cessna 182	Front seat observer	Howard Maimbo	Department of National Parks and Wildlife (DNPW)	Zambia
C01	V5IIM	Cessna 182	Front seat observer	Gregory Nyaguse	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C01	V5IIM	Cessna 182	Front seat observer	Malebogo Somolekae	Department of Wildlife and National Parks (DWNP)	Botswana
C01	V5IIM	Cessna 182	Pilot – P03	Jan Steyger	BushSkies	Namibia
C01	V5IIM	Cessna 182	Rear seat observer R	Ashley Mudungwe	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C01	V5IIM	Cessna 182	Rear seat observer L	Fungai Muroki	BushSkies	Zimbabwe
Crew	**Aircraft**	**Model**	**Role**	**Name**	**Affiliation**	**Country**
C02	V5LJB	Cessna 206	Data manager	Novald Iiyambo	Directorate of Wildlife and National Parks (DWNP)	Namibia
C02	V5LJB	Cessna 206	Data manager	Kuzivakwashe Mawoyo	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C02	V5LJB	Cessna 206	Front seat observer	Deborah Gibson	BushSkies	Namibia
C02	V5LJB	Cessna 206	Front seat observer	Johannes Le Roux	BushSkies	South Africa
C02	V5LJB	Cessna 206	Front seat observer	Gregory Nyaguse	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C02	V5LJB	Cessna 206	Pilot – P02	David Francis	BushSkies	Namibia
C02	V5LJB	Cessna 206	Rear seat observer L	Gabriel Shatumbu	Directorate of Wildlife and National Parks (DWNP)	Namibia
C02	V5LJB	Cessna 206	Rear seat observer R	Omphile Zweezwee	Department of Wildlife and National Parks (DWNP)	Botswana

Table A10.11b: List of personnel in each of the nine crews, continued.

Crew	Aircraft	Model	Role	Name	Affiliation	Country
C03	V5WOT	Cessna 182	Data manager	Christa D'Alton	BushSkies	Namibia
C03	V5WOT	Cessna 182	Data manager	Kuzivakwashe Mawoyo	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C03	V5WOT	Cessna 182	Front seat observer	Mathilde Brassine	Tourism Supporting Conservation Trust (TOSCO)	Belgium
C03	V5WOT	Cessna 182	Front seat observer	Deborah Gibson	BushSkies	Namibia
C03	V5WOT	Cessna 182	Front seat observer	Johannes Le Roux	BushSkies	South Africa
C03	V5WOT	Cessna 182	Front seat observer	Gregory Nyaguse	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C03	V5WOT	Cessna 182	Front seat observer	Malebogo Somolekae	Department of Wildlife and National Parks (DWNP)	Botswana
C03	V5WOT	Cessna 182	Pilot – P01	Johanco Steenkamp	BushSkies	South Africa
C03	V5WOT	Cessna 182	Rear seat observer R	Ngoni Chitemamuswe	BushSkies	Zimbabwe
C03	V5WOT	Cessna 182	Rear seat observer L	Hans Swartbooi	Directorate of Wildlife and National Parks (DWNP)	Namibia
Crew	Aircraft	Model	Role	Name	Affiliation	Country
C04	V5WOT	Cessna 182	Data manager	Christa D'Alton	BushSkies	Namibia
C04	V5WOT	Cessna 182	Data manager	Kuzivakwashe Mawoyo	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C04	V5WOT	Cessna 182	Front seat observer	Mwansa Chisanga	Department of National Parks and Wildlife (DNPW)	Zambia
C04	V5WOT	Cessna 182	Front seat observer	Deborah Gibson	BushSkies	Namibia
C04	V5WOT	Cessna 182	Front seat observer	Johannes Le Roux	BushSkies	South Africa
C04	V5WOT	Cessna 182	Front seat observer	Gregory Nyaguse	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C04	V5WOT	Cessna 182	Pilot – P01	Johanco Steenkamp	BushSkies	South Africa
C04	V5WOT	Cessna 182	Rear seat observer R	Anety Milimo	Department of National Parks and Wildlife (DNPW)	Zambia
C04	V5WOT	Cessna 182	Rear seat observer L	Hans Swartbooi	Directorate of Wildlife and National Parks (DWNP)	Namibia

Table A10.11c: List of personnel in each of the nine crews, continued.

Crew	Aircraft	Model	Role	Name	Affiliation	Country
C05	9JCMA	Cessna 206	Data manager	Clive Chifunte	Department of National Parks and Wildlife (DNPW)	Zambia
C05	9JCMA	Cessna 206	Data manager	Musonda Mwela	Department of National Parks and Wildlife (DNPW)	Zambia
C05	9JCMA	Cessna 206	Data manager	Debra Nachinga	Department of National Parks and Wildlife (DNPW)	Zambia
C05	9JCMA	Cessna 206	Data manager	Twakundine Simpamba	Department of National Parks and Wildlife (DNPW)	Zambia
C05	9JCMA	Cessna 206	Front seat observer	Howard Maimbo	Department of National Parks and Wildlife (DNPW)	Zambia
C05	9JCMA	Cessna 206	Pilot – P08	Timo Behr	Flying Mission Zambia	Zambia
C05	9JCMA	Cessna 206	Pilot – P04	Joel Bolthouse	Flying Mission Zambia	Zambia
C05	9JCMA	Cessna 206	Pilot – P07	Ian Lordanich	Flying Mission Zambia	Zambia
C05	9JCMA	Cessna 206	Rear seat observer L	Mwansa Chisanga	Department of National Parks and Wildlife (DNPW)	Zambia
C05	9JCMA	Cessna 206	Rear seat observer R	Anety Milimo	Department of National Parks and Wildlife (DNPW)	Zambia
Crew	Aircraft	Model	Role	Name	Affiliation	Country
C06	9JCMA	Cessna 206	Data manager	Clive Chifunte	Department of National Parks and Wildlife (DNPW)	Zambia
C06	9JCMA	Cessna 206	Data manager	Musonda Mwela	Department of National Parks and Wildlife (DNPW)	Zambia
C06	9JCMA	Cessna 206	Data manager	Debra Nachinga	Department of National Parks and Wildlife (DNPW)	Zambia
C06	9JCMA	Cessna 206	Data manager	Twakundine Simpamba	Department of National Parks and Wildlife (DNPW)	Zambia
C06	9JCMA	Cessna 206	Front seat observer	Darren Potgieter	Wild Sense	South Africa
C06	9JCMA	Cessna 206	Pilot – P10	Jason Speichinger	Flying Mission Zambia	Zambia
C06	9JCMA	Cessna 206	Rear seat observer R	Anety Milimo	Department of National Parks and Wildlife (DNPW)	Zambia
C06	9JCMA	Cessna 206	Rear seat observer L	Debra Nachinga	Department of National Parks and Wildlife (DNPW)	Zambia

Table A10.11d: List of personnel in each of the nine crews, continued.

Crew	Aircraft	Model	Role	Name	Affiliation	Country
C07	9JMFZ	Cessna 206	Data manager	Clive Chifunte	Department of National Parks and Wildlife (DNPW)	Zambia
C07	9JMFZ	Cessna 206	Data manager	Musonda Mwela	Department of National Parks and Wildlife (DNPW)	Zambia
C07	9JMFZ	Cessna 206	Data manager	Debra Nachinga	Department of National Parks and Wildlife (DNPW)	Zambia
C07	9JMFZ	Cessna 206	Data manager	Twakundine Simpamba	Department of National Parks and Wildlife (DNPW)	Zambia
C07	9JMFZ	Cessna 206	Front seat observer	Saferana Banda	Department of National Parks and Wildlife (DNPW)	Zambia
C07	9JMFZ	Cessna 206	Pilot – P08	Timo Behr	Flying Mission Zambia	Zambia
C07	9JMFZ	Cessna 206	Pilot – P07	Ian Lordanich	Flying Mission Zambia	Zambia
C07	9JMFZ	Cessna 206	Pilot – P05	Lukas Schmidt	Flying Mission Zambia	Zambia
C07	9JMFZ	Cessna 206	Rear seat observer R	Adrian Kaluka	Department of National Parks and Wildlife (DNPW)	Zambia
C07	9JMFZ	Cessna 206	Rear seat observer L	Talison Tembo	Department of National Parks and Wildlife (DNPW)	Zambia
Crew	**Aircraft**	**Model**	**Role**	**Name**	**Affiliation**	**Country**
C08	ZYYB	Cessna 182	Data manager	Fay Robertson	BushSkies	Zimbabwe
C08	ZYYB	Cessna 182	Front seat observer	Kevin Dunham	BushSkies	Zimbabwe
C08	ZYYB	Cessna 182	Pilot – P06	Raymond Paul	BushSkies	Zimbabwe
C08	ZYYB	Cessna 182	Rear seat observer L	Ezekiel Mungoni	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
C08	ZYYB	Cessna 182	Rear seat observer R	Gregory Nyaguse	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
Crew	**Aircraft**	**Model**	**Role**	**Name**	**Affiliation**	**Country**
C09	ZYVY	Piper Super Cub	Data manager	Fay Robertson	BushSkies	Zimbabwe
C09	ZYVY	Piper Super Cub	Front seat observer	Kevin Dunham	BushSkies	Zimbabwe
C09	ZYVY	Piper Super Cub	Pilot – P09	Caroline Puzey	BushSkies	Zimbabwe
C09	ZYVY	Piper Super Cub	Rear seat observer	Ed Mordt	Executive Air	Zimbabwe

Table A10.12: List of personnel involved in the analysis of the KAZA Elephant Survey (2022) data

Name	Role	Occupation	Affiliation	Country
Novald Iiyambo	Data analyst	Senior conservation scientist	Directorate of Wildlife and National Parks (DWNP)	Namibia
Terence Magquina	Data analyst	Ecologist	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
Kuzivakwashe Mawoyo	Data analyst	Ecologist	Zimbabwe Parks and Wildlife Authority (ZPWMA)	Zimbabwe
Charles Mpofu	Data analyst	Wildlife Biologist	Department of Wildlife and National Parks (DWNP)	Botswana
Debra Nachinga	Data analyst	Ecologist	Department of National Parks and Wildlife (DNPW)	Zambia
Basutli Ramakawa	Data analyst	Wildlife biologist	Department of Wildlife and National Parks (DWNP)	Botswana
Tirelo Shabane	Data analyst	Senior wildlife biologist	Department of Wildlife and National Parks (DWNP)	Botswana
Dr. Elsa Bussière	Science and technology manager	Conservation biologist	Wild Sense	France
Darren Potgieter	Survey coordinator	Pilot, survey biologist, executive director	Wild Sense	South Africa

Appendix 11: Stratum information.

Table A11.1: Stratum information.

Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Angola	Luengue-Luiana	CUON	3474	5.36	1.09	92	172	180	318	30	2.0452
Angola	Luengue-Luiana	KAN	1768	6.35	1.12	91	170	80	315	15	2.1448
Angola	Luengue-Luiana	KW5	2496	5.18	1.12	91	172	101	309	17	2.1199
Angola	Luengue-Luiana	KWN	1629	6.32	1.10	92	171	79	317	15	2.1448
Angola	Luengue-Luiana	L10E	1764	3.44	1.12	90	170	81	312	8	2.3646
Angola	Luengue-Luiana	L10W	2971	3.27	1.12	92	169	82	316	8	2.3646
Angola	Luengue-Luiana	LI	2355	5.73	1.10	91	173	103	316	18	2.1098
Angola	Luengue-Luiana	LIK	1931	4.66	1.11	90	173	47	311	7	2.4469
Angola	Luengue-Luiana	MUCE	1918	5.44	1.11	92	169	105	317	17	2.1199
Angola	Luengue-Luiana	MUCW	2011	5.02	1.14	90	171	81	304	14	2.1604
Angola	Luengue-Luiana	WLC	4276	3.25	1.09	91	174	77	316	8	2.3646
Angola	Luengue-Luiana	WLE	4703	2.91	1.16	90	170	129	303	12	2.2010
Angola	Luengue-Luiana	WLW	5047	3.01	1.13	90	171	81	310	8	2.3646
Botswana	Northern Botswana	1819	1986	5.65	1.11	92	171	55	314	10	2.2622
Botswana	Northern Botswana	2730	1346	9.63	1.10	93	168	73	321	22	2.0796
Botswana	Northern Botswana	1&2H	2888	2.93	1.14	90	170	89	307	8	2.3646
Botswana	Northern Botswana	1&2L	4378	3.17	1.09	92	173	97	318	10	2.2622
Botswana	Northern Botswana	14HBW	1312	25.39	1.11	92	171	68	321	54	2.0140
Botswana	Northern Botswana	C4&7	3084	3.29	1.11	93	169	66	321	7	2.4469
Botswana	Northern Botswana	CH13	1177	10.80	1.11	92	171	54	317	17	2.1199
Botswana	Northern Botswana	CH1BW	1305	10.56	1.11	93	168	54	320	17	2.1199

Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Botswana	Northern Botswana	CH2H	494	10.78	1.11	93	166	42	320	14	2.1604
Botswana	Northern Botswana	CH2L	849	5.42	1.14	93	165	52	321	9	2.3060
Botswana	Northern Botswana	CH5	1428	5.24	1.13	92	169	53	312	8	2.3646
Botswana	Northern Botswana	CHZW	945	6.05	1.08	92	173	32	319	6	2.5706
Botswana	Northern Botswana	CRBW	1520	8.57	1.08	92	173	79	320	21	2.0860
Botswana	Northern Botswana	CT3	1236	5.25	1.12	89	173	47	309	8	2.3646
Botswana	Northern Botswana	KFRS	433	5.73	1.14	90	171	26	306	5	2.7765
Botswana	Northern Botswana	KRDE	1921	6.55	1.08	92	173	69	320	14	2.1604
Botswana	Northern Botswana	KZFR	168	9.44	1.09	92	173	16	314	4	3.1825
Botswana	Northern Botswana	LIAMBW	249	5.19	1.10	92	171	26	316	5	2.7765
Botswana	Northern Botswana	MAC	3723	5.16	1.08	93	173	68	320	11	2.2281
Botswana	Northern Botswana	MN	1694	4.10	1.13	92	166	74	318	9	2.3060
Botswana	Northern Botswana	MNEE	4349	3.29	1.09	93	173	97	315	10	2.2622
Botswana	Northern Botswana	MNPE	2249	4.18	1.14	92	167	43	318	6	2.5706
Botswana	Northern Botswana	MNPP	1975	6.21	1.13	92	166	72	319	15	2.1448
Botswana	Northern Botswana	MNPS	641	5.38	1.14	91	164	23	315	4	3.1825
Botswana	Northern Botswana	MNW	1903	5.04	1.14	92	166	63	316	10	2.2622
Botswana	Northern Botswana	MOE	2864	11.74	1.07	93	176	71	319	26	2.0595
Botswana	Northern Botswana	MOTK	425	9.40	1.08	93	175	20	318	6	2.5706
Botswana	Northern Botswana	MOW	1543	11.63	1.12	92	170	48	315	18	2.1098
Botswana	Northern Botswana	MSBW	346	20.98	1.10	93	172	46	316	30	2.0452
Botswana	Northern Botswana	N14L	1448	5.27	1.12	92	170	64	315	11	2.2281
Botswana	Northern Botswana	N1SW	1820	2.57	1.13	91	169	61	314	5	2.7765
Botswana	Northern Botswana	N3NE	4167	2.80	1.10	93	169	70	321	6	2.5706

Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Botswana	Northern Botswana	N3NW	4262	2.68	1.12	92	172	73	309	6	2.5706
Botswana	Northern Botswana	N3SE	3168	2.71	1.10	92	170	83	318	7	2.4469
Botswana	Northern Botswana	N41L	3032	3.83	1.10	92	172	81	313	10	2.2622
Botswana	Northern Botswana	N42S	2882	3.94	1.11	92	172	97	312	12	2.2010
Botswana	Northern Botswana	NATA	2482	5.31	1.09	93	173	81	316	13	2.1788
Botswana	Northern Botswana	NG11	5417	8.51	1.10	92	172	134	316	36	2.0301
Botswana	Northern Botswana	NG12	999	11.44	1.13	91	171	51	310	19	2.1009
Botswana	Northern Botswana	NG13	2504	3.09	1.09	92	172	84	319	9	2.3060
Botswana	Northern Botswana	NG15	932	5.53	1.11	92	173	35	309	6	2.5706
Botswana	Northern Botswana	NG16	1383	7.95	1.06	93	175	58	321	14	2.1604
Botswana	Northern Botswana	NG1BW	1923	2.62	1.12	91	173	60	307	5	2.7765
Botswana	Northern Botswana	NG20	1775	12.13	1.11	92	171	46	314	18	2.1098
Botswana	Northern Botswana	NG22	684	12.39	1.09	93	171	26	321	10	2.2622
Botswana	Northern Botswana	NG23	468	7.04	1.09	92	172	29	318	6	2.5706
Botswana	Northern Botswana	NG24	672	4.90	1.08	92	173	31	319	5	2.7765
Botswana	Northern Botswana	NG25	617	7.29	1.12	90	173	20	306	5	2.7765
Botswana	Northern Botswana	NG26	1652	8.92	1.14	92	165	49	317	14	2.1604
Botswana	Northern Botswana	NG29	1921	7.23	1.09	92	171	53	319	12	2.2010
Botswana	Northern Botswana	NG31	287	10.07	1.08	93	173	18	322	6	2.5706
Botswana	Northern Botswana	NG32	1233	10.61	1.08	93	174	42	321	14	2.1604
Botswana	Northern Botswana	NG40	3732	4.15	1.08	93	172	71	323	9	2.3060
Botswana	Northern Botswana	NGWN	842	13.14	1.13	92	169	47	313	19	2.1009
Botswana	Northern Botswana	NGWS	2096	10.60	1.12	92	168	72	316	24	2.0687
Botswana	Northern Botswana	NOGA	3091	5.47	1.11	93	168	70	321	12	2.2010

Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Botswana	Northern Botswana	NXC	1065	4.85	1.12	92	171	26	312	4	3.1825
Botswana	Northern Botswana	NXN	766	5.50	1.14	91	169	28	310	5	2.7765
Botswana	Northern Botswana	NXS	814	5.50	1.10	93	173	29	315	5	2.7765
Botswana	Northern Botswana	PAND	820	5.73	1.13	90	173	34	306	7	2.4469
Botswana	Northern Botswana	SAVE	834	6.11	1.13	92	167	26	318	5	2.7765
Botswana	Northern Botswana	SAVM	2128	4.12	1.11	92	170	69	317	9	2.3060
Botswana	Northern Botswana	SAVN	1914	7.89	1.12	92	172	50	309	13	2.1788
Botswana	Northern Botswana	SK	3470	3.25	1.08	93	174	89	320	9	2.3060
Botswana	Northern Botswana	SUSH	906	7.12	1.08	93	171	32	323	7	2.4469
Botswana	Northern Botswana	WOKS	3636	5.38	1.08	93	172	155	323	26	2.0595
Botswana	Northern Botswana	WONE	3391	4.65	1.10	93	169	72	322	10	2.2622
Namibia	Kavango Zambezi	14HNA	165	24.81	1.10	93	172	37	321	30	2.1320
Namibia	Kavango Zambezi	BUF	1177	31.29	1.11	92	171	32	315	32	2.0395
Namibia	Kavango Zambezi	BWA	3811	3.17	1.12	92	168	132	319	13	2.1788
Namibia	Kavango Zambezi	CH1NA	294	10.10	1.12	93	168	55	319	17	2.1199
Namibia	Kavango Zambezi	CRNA	274	8.65	1.08	94	173	79	324	21	2.0860
Namibia	Kavango Zambezi	EZN	4792	3.15	1.09	92	174	175	314	17	2.1199
Namibia	Kavango Zambezi	KWZ	1057	17.92	1.13	92	169	37	315	21	2.0860
Namibia	Kavango Zambezi	KWZN	686	5.49	1.09	94	169	40	326	7	2.4469
Namibia	Kavango Zambezi	LIAMNA	1074	5.22	1.11	92	170	39	314	7	2.4469
Namibia	Kavango Zambezi	MSNA	391	21.12	1.11	93	172	38	315	25	2.0639
Namibia	Kavango Zambezi	NG1NA	515	2.61	1.11	92	173	50	309	4	3.1825
Namibia	Kavango Zambezi	SALI	1003	5.50	1.09	92	176	59	313	10	2.2622
Namibia	Kavango Zambezi	SUS	1171	31.35	1.09	93	172	37	319	36	2.0301

Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Namibia	Kavango Zambezi	ZASW	1647	3.00	1.11	93	168	63	320	6	2.5706
Namibia	Khaudum Nyae-Nyae	KC	1343	10.53	1.11	90	174	52	311	18	2.1098
Namibia	Khaudum Nyae-Nyae	KL1	1414	5.21	1.09	92	173	95	318	15	2.1448
Namibia	Khaudum Nyae-Nyae	KL2	568	4.57	1.10	91	173	43	316	6	2.5706
Namibia	Khaudum Nyae-Nyae	KN	1715	8.11	1.10	91	172	52	313	14	2.1604
Namibia	Khaudum Nyae-Nyae	KS	791	4.58	1.09	93	176	33	311	5	2.7765
Namibia	Khaudum Nyae-Nyae	L1	3631	3.18	1.09	92	173	119	318	12	2.2010
Namibia	Khaudum Nyae-Nyae	T1	1839	2.91	1.12	92	168	53	318	5	2.7765
Namibia	Khaudum Nyae-Nyae	TS1	964	5.17	1.09	93	171	37	320	6	2.5706
Namibia	Khaudum Nyae-Nyae	TS2	1555	5.24	1.12	92	172	58	309	10	2.2622
Namibia	Khaudum Nyae-Nyae	TS3	1436	10.33	1.10	92	171	55	319	18	2.1098
Namibia	Khaudum Nyae-Nyae	TS6	1311	6.97	1.10	92	172	58	317	13	2.1788
Namibia	Khaudum Nyae-Nyae	TS7	1738	10.42	1.12	92	174	53	308	18	2.1098
Transfrontier	Transfrontier	LIAM	1323	5.27	1.11	92	171	39	315	7	2.4469
Transfrontier	Transfrontier	MS	736	21.08	1.10	93	172	46	315	30	2.0452
Transfrontier	Transfrontier	14H	1481	24.98	1.11	92	171	68	321	54	2.0160
Transfrontier	Transfrontier	CH1	1600	10.42	1.11	93	168	55	320	17	2.1199
Transfrontier	Transfrontier	CR	1794	8.65	1.08	93	173	78	321	21	2.0860
Transfrontier	Transfrontier	NG1	2439	2.64	1.12	91	173	60	307	5	2.7765
Zambia	Kafue	A1	2457	10.06	1.09	93	175	61	313	19	2.1009
Zambia	Kafue	A2	2065	10.09	1.16	88	173	60	298	21	2.0860
Zambia	Kafue	A3	1468	9.92	1.14	88	176	65	297	22	2.0796
Zambia	Kafue	C1	1456	10.26	1.16	91	170	32	304	11	2.2281
Zambia	Kafue	C2	2643	10.26	1.13	91	171	88	308	28	2.0518

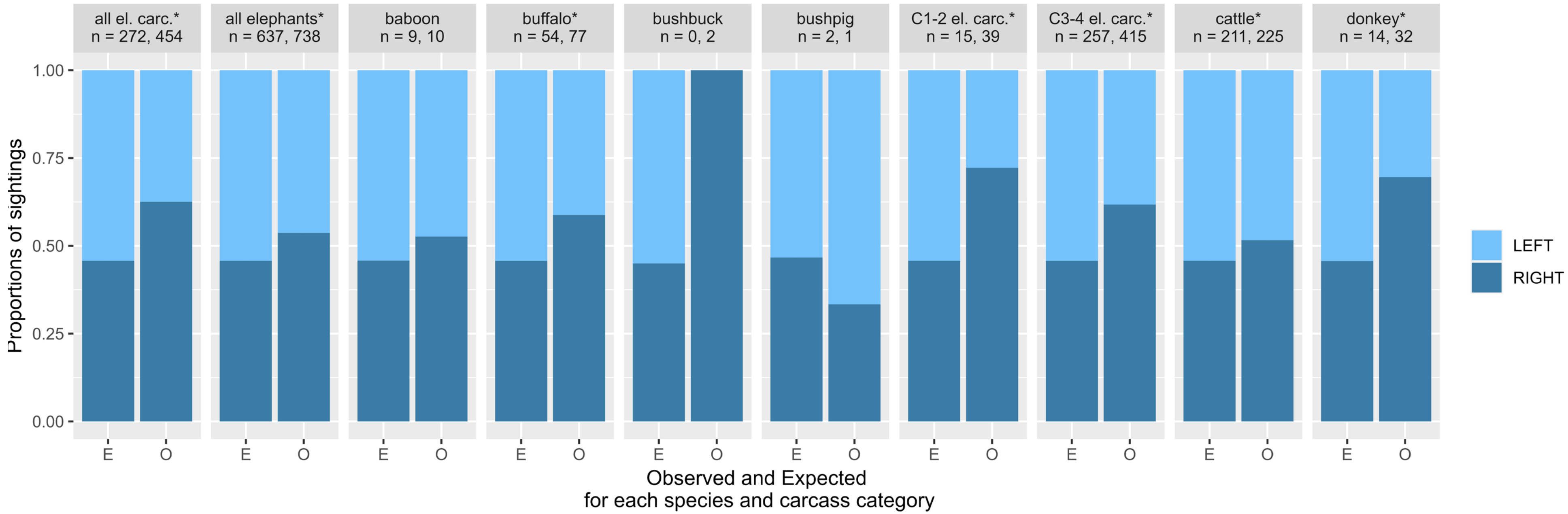
Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Zambia	Kafue	C3	1046	9.21	1.21	87	169	25	291	8	2.3646
Zambia	Kafue	D	1372	9.76	1.16	89	173	32	297	11	2.2281
Zambia	Kafue	E	3093	10.16	1.15	90	170	75	304	25	2.0639
Zambia	Kafue	F	1805	10.00	1.15	91	171	57	305	19	2.1009
Zambia	Kafue	G	1370	9.80	1.21	88	169	63	291	21	2.0860
Zambia	Kafue	G2	1999	5.08	1.14	89	172	69	304	11	2.2281
Zambia	Kafue	HE	3413	10.01	1.13	88	175	107	301	35	2.0322
Zambia	Kafue	HW	3394	10.13	1.15	89	172	114	303	37	2.0281
Zambia	Kafue	J2	2724	4.78	1.19	87	174	106	289	17	2.1199
Zambia	Kafue	K	2296	4.93	1.17	89	173	78	295	13	2.1788
Zambia	Kafue	L	3331	9.95	1.18	89	171	93	298	31	2.0423
Zambia	Kafue	L2	2914	4.57	1.21	88	169	69	293	11	2.2281
Zambia	Kafue	LCW	525	25.17	1.17	90	170	41	301	35	2.0322
Zambia	Kafue	M	1230	9.98	1.18	90	168	46	302	15	2.1448
Zambia	Kafue	N	3909	10.23	1.15	91	170	101	306	33	2.0369
Zambia	Kafue	Q1	3762	2.83	1.17	87	176	73	290	7	2.4469
Zambia	Kafue	Q2	3841	3.06	1.09	88	182	85	301	8	2.3646
Zambia	Kafue	Q3	3906	2.76	1.13	89	175	79	303	7	2.4469
Zambia	Kafue	S1	3132	5.12	1.15	92	169	73	307	12	2.2010
Zambia	Kafue	S2	1429	5.23	1.13	91	170	35	311	5	2.7765
Zambia	Kafue	T	3824	10.40	1.14	91	170	78	309	26	2.0595
Zambia	Sioma	LWZGE	2033	6.22	1.12	92	170	75	314	14	2.1604
Zambia	Sioma	LWZGN	2408	6.49	1.14	92	169	72	313	15	2.1448
Zambia	Sioma	LWZGW	1026	6.34	1.15	92	174	64	299	13	2.1788

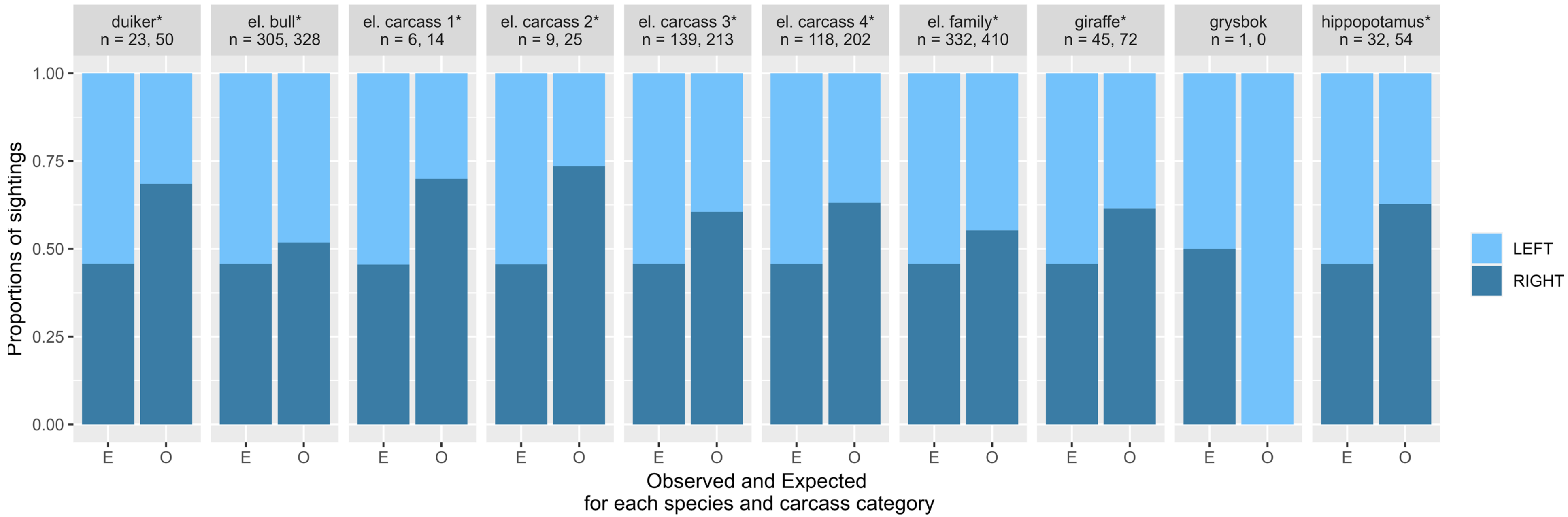
Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Zambia	Sioma	SIA	2208	12.49	1.09	93	174	70	316	28	2.0518
Zambia	Sioma	SIB	2275	12.49	1.07	93	175	70	318	27	2.0555
Zimbabwe	North-West Matabeleland	CENA	769	9.62	1.09	93	170	45	323	13	2.1788
Zimbabwe	North-West Matabeleland	CENB	1721	4.23	1.22	85	171	43	290	6	2.5706
Zimbabwe	North-West Matabeleland	DAN	1280	10.79	1.08	93	172	72	323	23	2.0739
Zimbabwe	North-West Matabeleland	DZI	2097	7.03	1.11	93	169	62	317	13	2.1788
Zimbabwe	North-West Matabeleland	KAZZ	551	5.36	1.07	93	172	32	324	5	2.7765
Zimbabwe	North-West Matabeleland	KZ	435	5.26	1.08	90	178	35	312	6	2.5706
Zimbabwe	North-West Matabeleland	MAIT	1204	5.17	1.09	92	172	51	318	8	2.3646
Zimbabwe	North-West Matabeleland	MC	1254	16.93	1.10	93	170	51	320	26	2.1210
Zimbabwe	North-West Matabeleland	MT	703	21.07	1.11	92	171	41	312	28	2.1220
Zimbabwe	North-West Matabeleland	MTOA	825	13.19	1.05	96	174	53	328	21	2.0860
Zimbabwe	North-West Matabeleland	NGAM	1631	14.09	1.04	93	180	56	322	24	2.0687
Zimbabwe	North-West Matabeleland	NGFR	1175	6.64	1.22	92	171	44	316	8	2.3646
Zimbabwe	North-West Matabeleland	PMUS	1006	8.74	1.14	87	174	55	304	15	2.1448
Zimbabwe	North-West Matabeleland	ROB	1018	10.44	1.11	95	167	35	324	11	2.2281
Zimbabwe	North-West Matabeleland	ROSS	349	7.30	1.10	94	169	21	318	5	2.7765
Zimbabwe	North-West Matabeleland	SH	914	17.21	1.08	93	172	57	327	30	2.0590
Zimbabwe	North-West Matabeleland	SHAK	2149	5.37	1.11	94	170	66	317	11	2.2281
Zimbabwe	North-West Matabeleland	SIKF	1159	4.39	1.03	94	178	60	325	8	2.3646
Zimbabwe	North-West Matabeleland	SIN	1529	11.14	1.03	94	175	56	326	20	2.0930
Zimbabwe	North-West Matabeleland	TSHE	922	6.90	1.08	93	171	57	322	12	2.2010
Zimbabwe	North-West Matabeleland	TSHN	959	4.35	1.03	96	178	73	326	10	2.2622
Zimbabwe	North-West Matabeleland	ZANG	847	9.08	1.07	95	171	38	326	10	2.2622
Zimbabwe	North-West Matabeleland	ZNP	550	5.39	1.00	102	179	31	342	6	2.5706

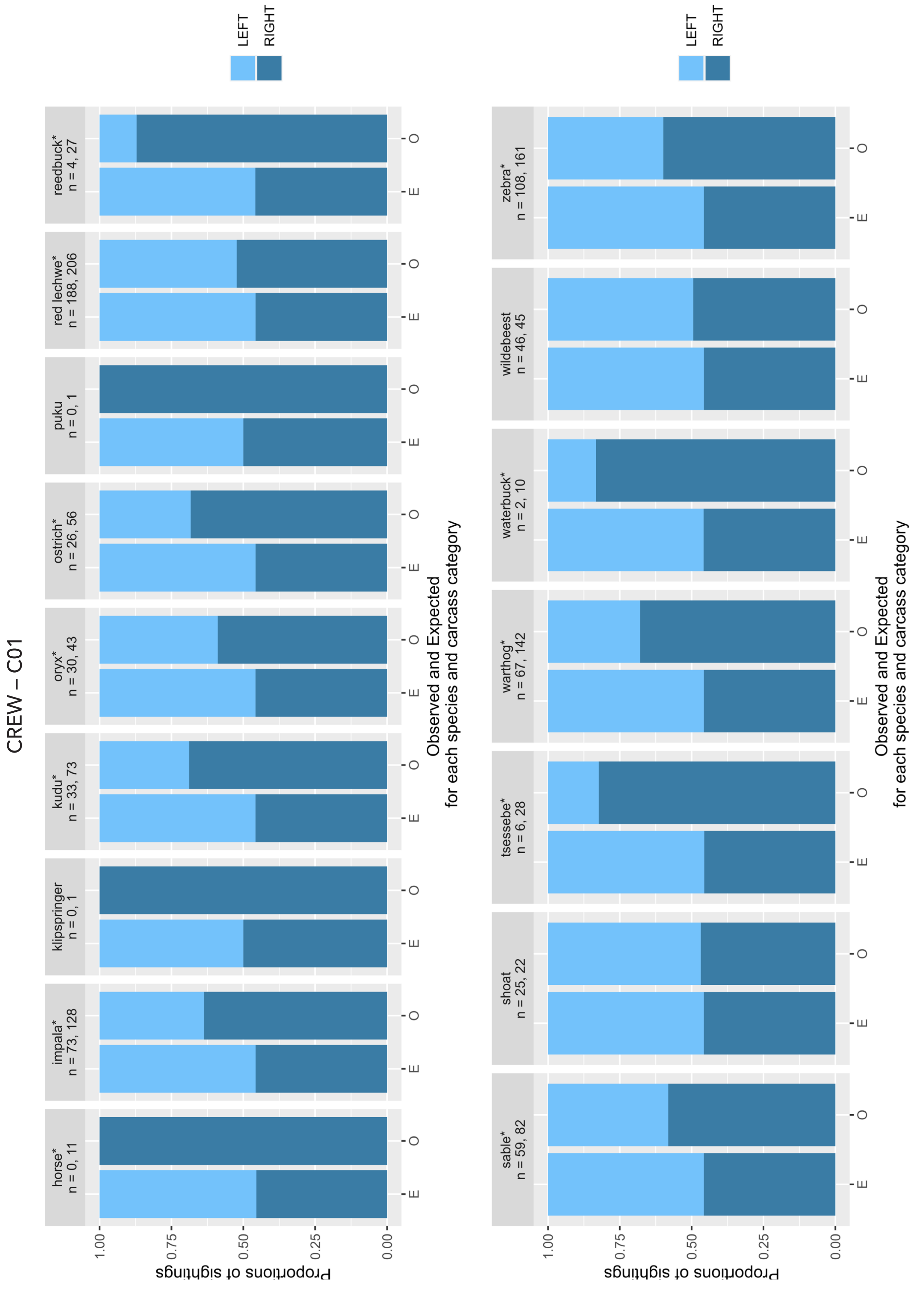
Country	Superstratum	Stratum Code	Stratum Area	Sampling Intensity	Search Effort	Mean Height	Mean Speed	Baseline length	Search Strip Width (300ft)	Number of Transects	Student t
Zimbabwe	Sebungwe	BS	445	18.60	1.18	92	171	25	297	16	2.1315
Zimbabwe	Sebungwe	CE	501	9.74	1.21	92	171	29	292	10	2.2622
Zimbabwe	Sebungwe	CG	555	17.11	1.23	91	170	31	289	19	2.1009
Zimbabwe	Sebungwe	CN	430	5.17	1.19	93	168	29	298	5	2.7765
Zimbabwe	Sebungwe	CS	1571	4.12	1.25	91	164	69	296	10	2.2622
Zimbabwe	Sebungwe	CW	741	11.41	1.26	90	178	42	286	17	2.1199
Zimbabwe	Sebungwe	GG	100	12.23	1.15	92	175	18	297	8	2.3646
Zimbabwe	Sebungwe	KH	307	56.02	0.71	-	-	-	-	7	2.4469
Zimbabwe	Sebungwe	LU	537	3.87	1.23	91	169	45	291	6	2.5706
Zimbabwe	Sebungwe	MD	458	10.02	1.20	94	165	29	298	9	2.3060
Zimbabwe	Sebungwe	ME	296	17.08	1.16	93	176	31	295	18	2.1098
Zimbabwe	Sebungwe	MH	1006	23.91	1.00	-	-	-	-	10	2.2622
Zimbabwe	Sebungwe	MP	377	13.31	1.14	97	169	24	312	10	2.2622
Zimbabwe	Sebungwe	MW	116	17.80	1.24	87	168	17	287	11	2.2281
Zimbabwe	Sebungwe	NG	714	7.57	1.21	93	172	38	296	10	2.2622
Zimbabwe	Sebungwe	NN	495	8.84	1.16	93	166	27	307	8	2.3646
Zimbabwe	Sebungwe	RA	373	18.89	1.30	87	163	21	283	15	2.1448
Zimbabwe	Sebungwe	SB	718	8.74	1.19	93	170	43	297	13	2.1788
Zimbabwe	Sebungwe	SE	1295	4.12	1.12	94	173	50	308	7	2.4469
Zimbabwe	Sebungwe	SG	414	15.70	1.24	93	165	29	295	16	2.1315
Zimbabwe	Sebungwe	SJ	261	13.03	1.21	93	172	17	292	8	2.3646
Zimbabwe	Sebungwe	SM	788	4.62	1.22	92	168	47	293	7	2.4469
Zimbabwe	Sebungwe	SP	991	10.28	1.20	96	168	51	303	18	2.1098
Zimbabwe	Sebungwe	SW	481	4.22	1.21	90	172	48	292	8	2.3646
Zimbabwe	Sebungwe	ZE	968	12.16	1.23	92	170	28	293	11	2.2281
Zimbabwe	Sebungwe	ZW	683	15.81	1.16	93	171	34	296	17	2.1199

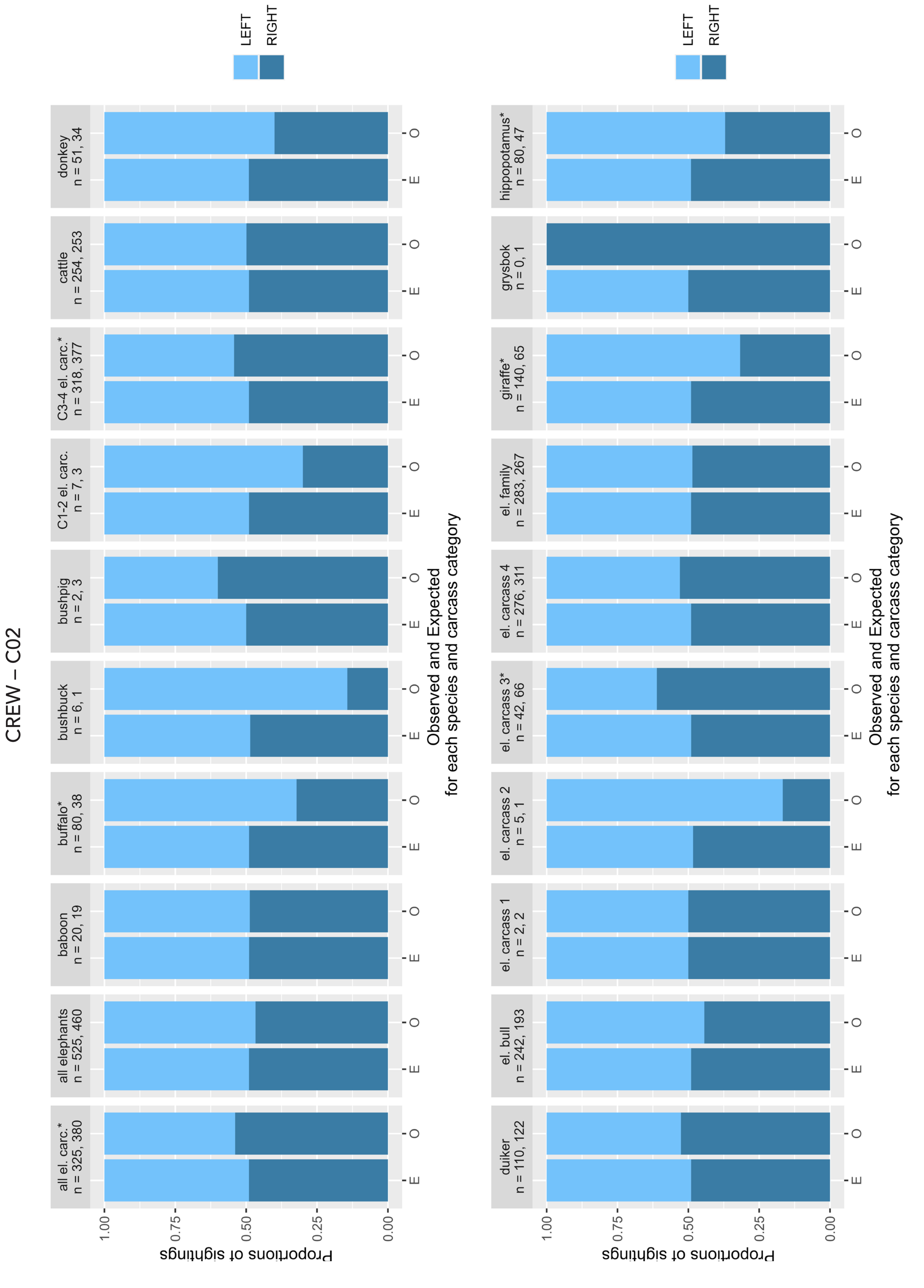
Appendix 12: Comparing announced and expected number of observations for each crew.

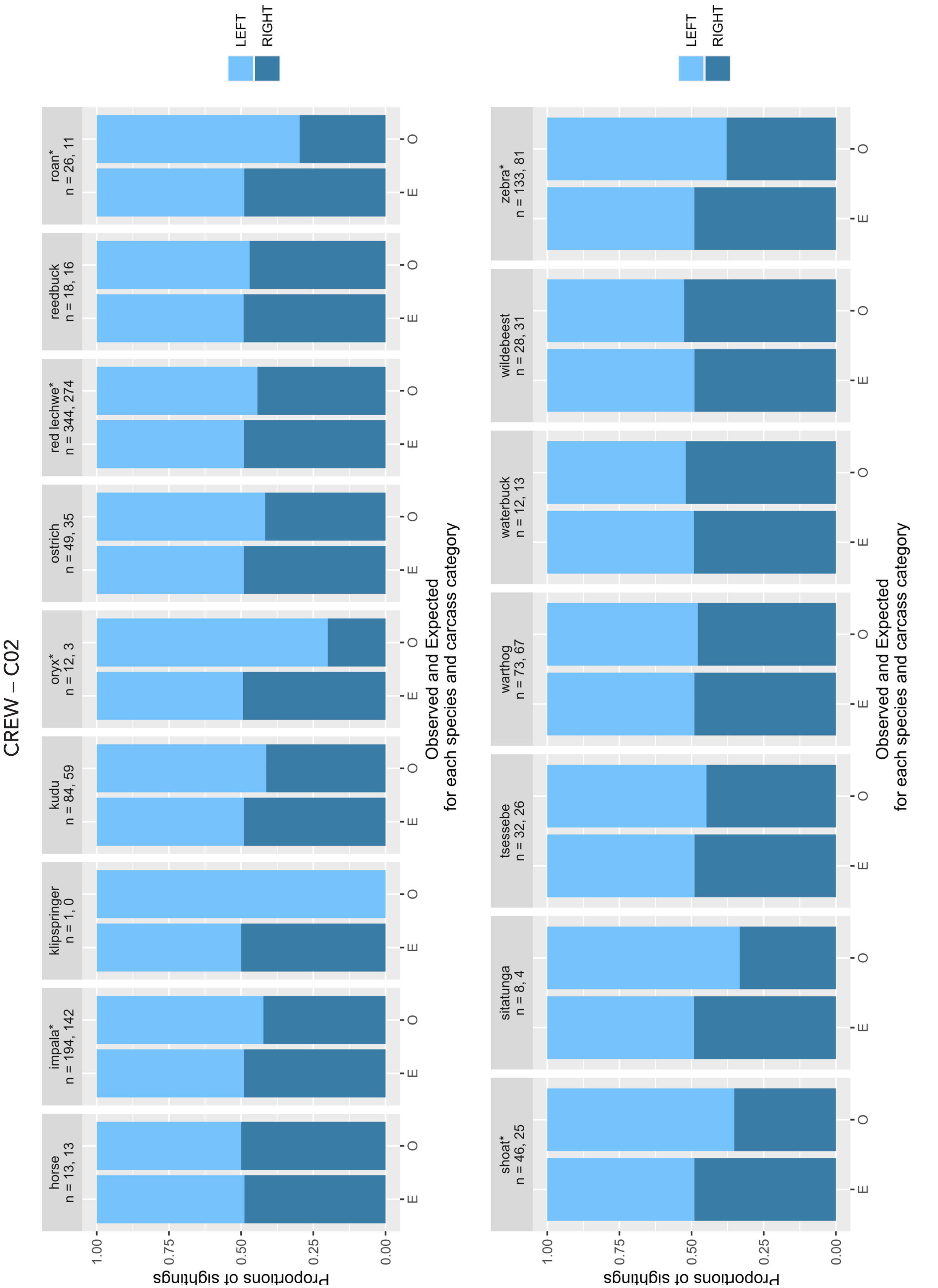
CREW – C01

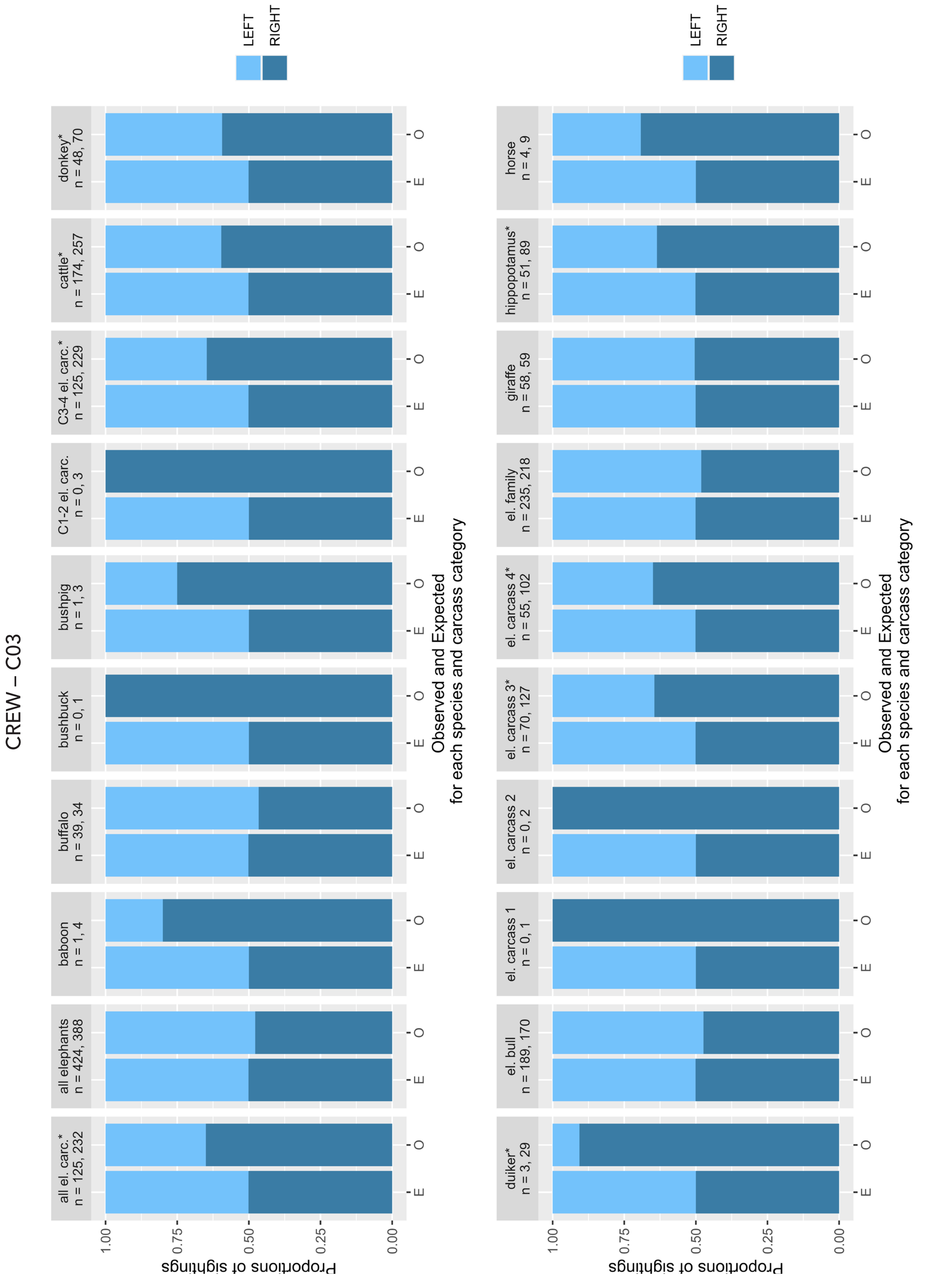


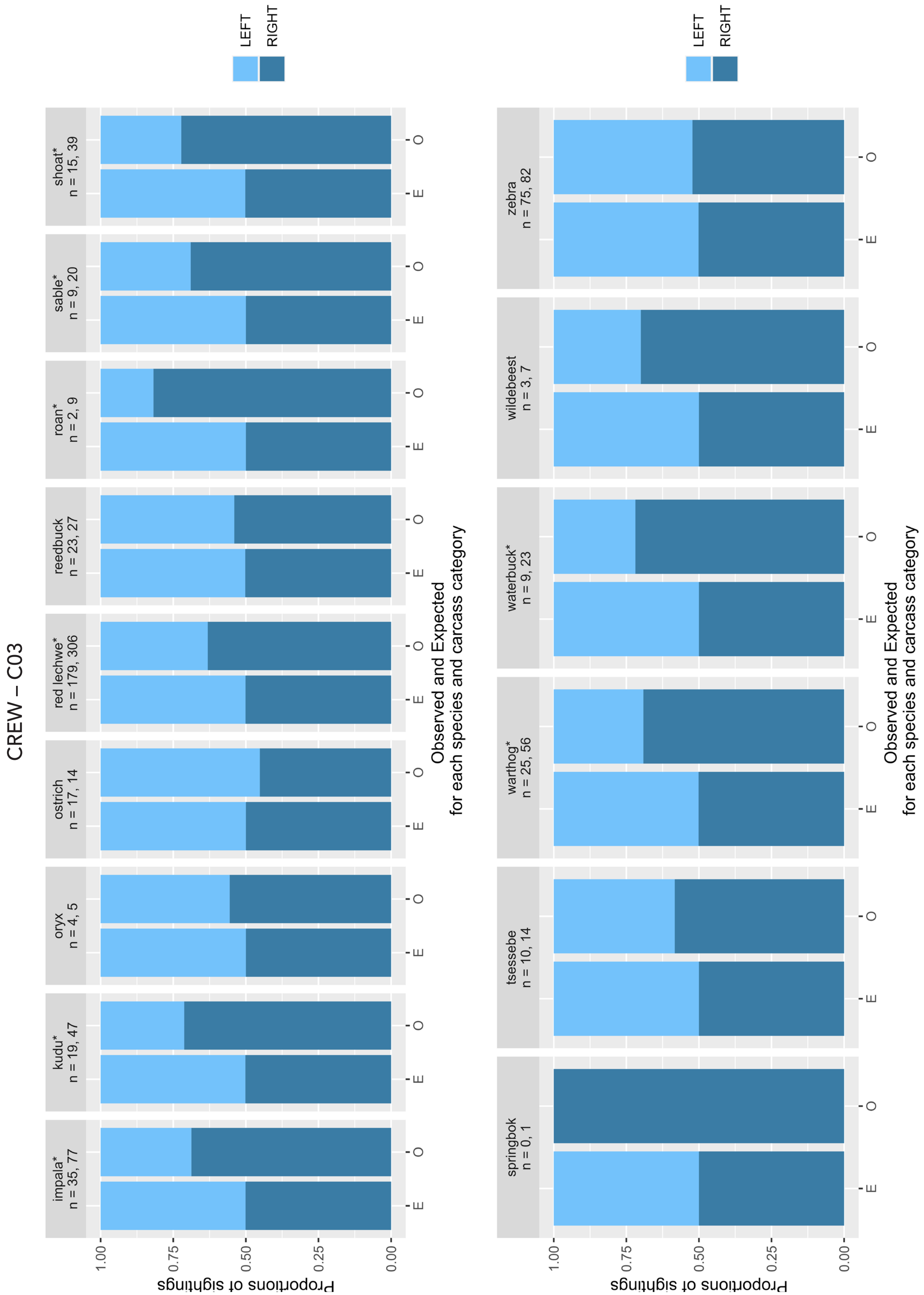


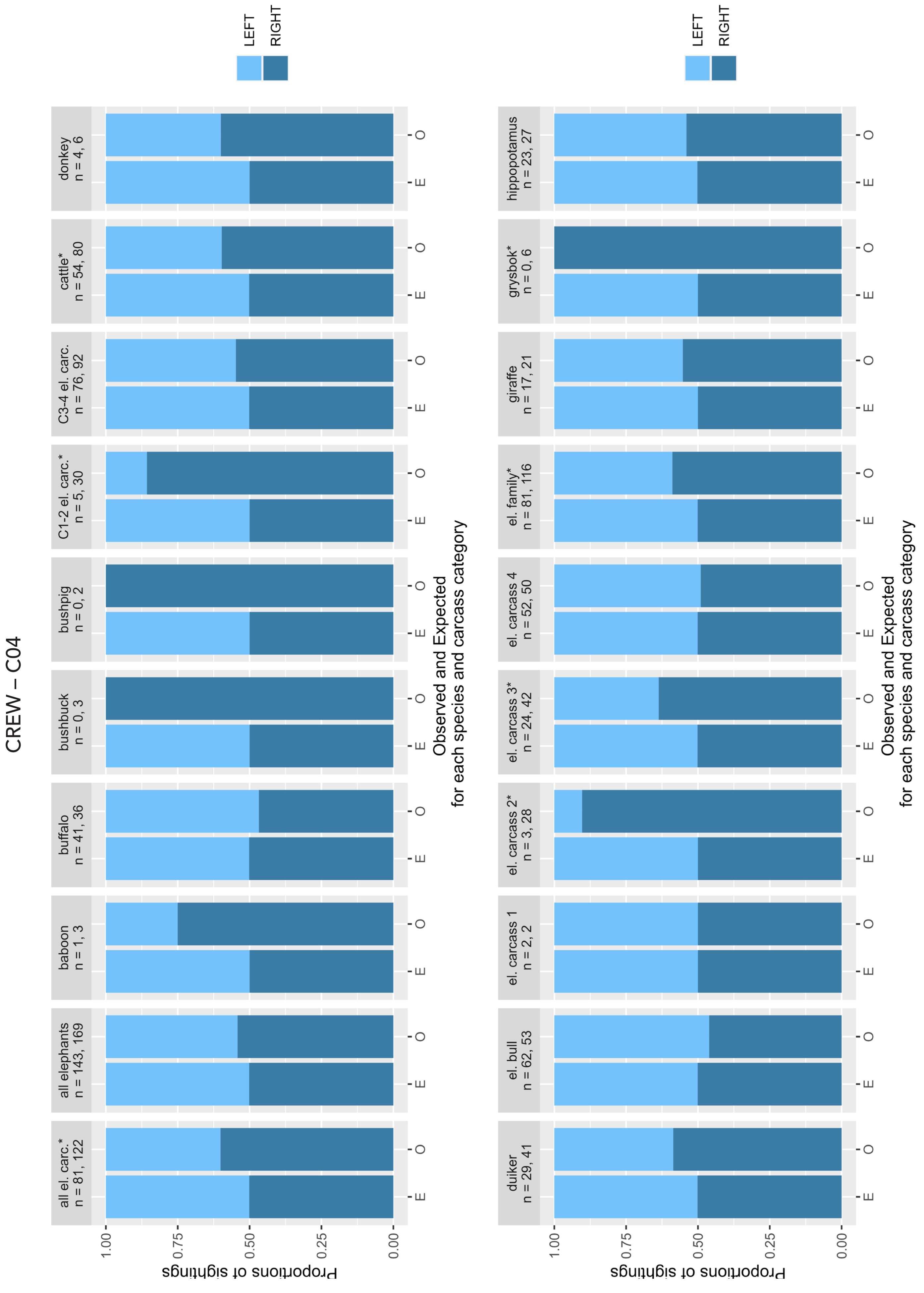

CREW – C01
LEFT
RIGHT
horse* n = 0, 11
impala* n = 73, 128
klipspringer n = 0, 1
kudu* n = 33, 73
oryx* n = 30, 43
ostrich* n = 26, 56
puku n = 0, 1
red lechwe* n = 188, 206
reedbuck* n = 4, 27
sable* n = 59, 82
shoat n = 25, 22
tsessebe* n = 6, 28
warthog* n = 67, 142
waterbuck* n = 2, 10
wildebeest n = 46, 45
zebra* n = 108, 161
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category

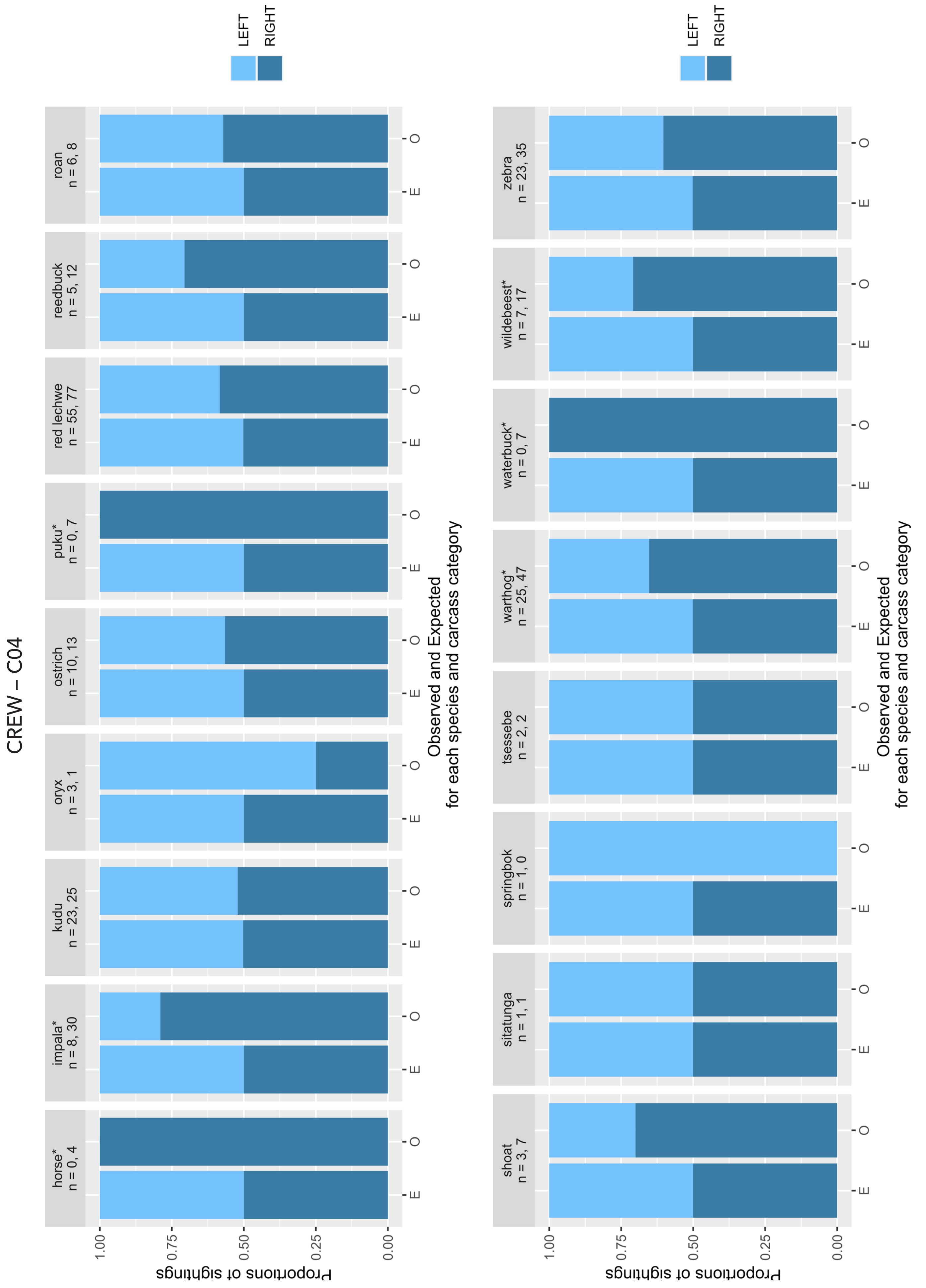

CREW – C02
all el. carc.* n = 325, 380
all elephants n = 525, 460
baboon n = 20, 19
buffalo* n = 80, 38
bushbuck n = 6, 1
bushpig n = 2, 3
C1-2 el. carc. n = 7, 3
C3-4 el. carc.* n = 318, 377
cattle n = 254, 253
donkey n = 51, 34
duiker n = 110, 122
el. bull n = 242, 193
el. carcass 1 n = 2, 2
el. carcass 2 n = 5, 1
el. carcass 3* n = 42, 66
el. carcass 4 n = 276, 311
el. family n = 283, 267
giraffe* n = 140, 65
grysbok n = 0, 1
hippopotamus* n = 80, 47
E
O
1.00
0.75
0.50
0.25
0.00
Proportions of sightings
Observed and Expected for each species and carcass category
LEFT
RIGHT

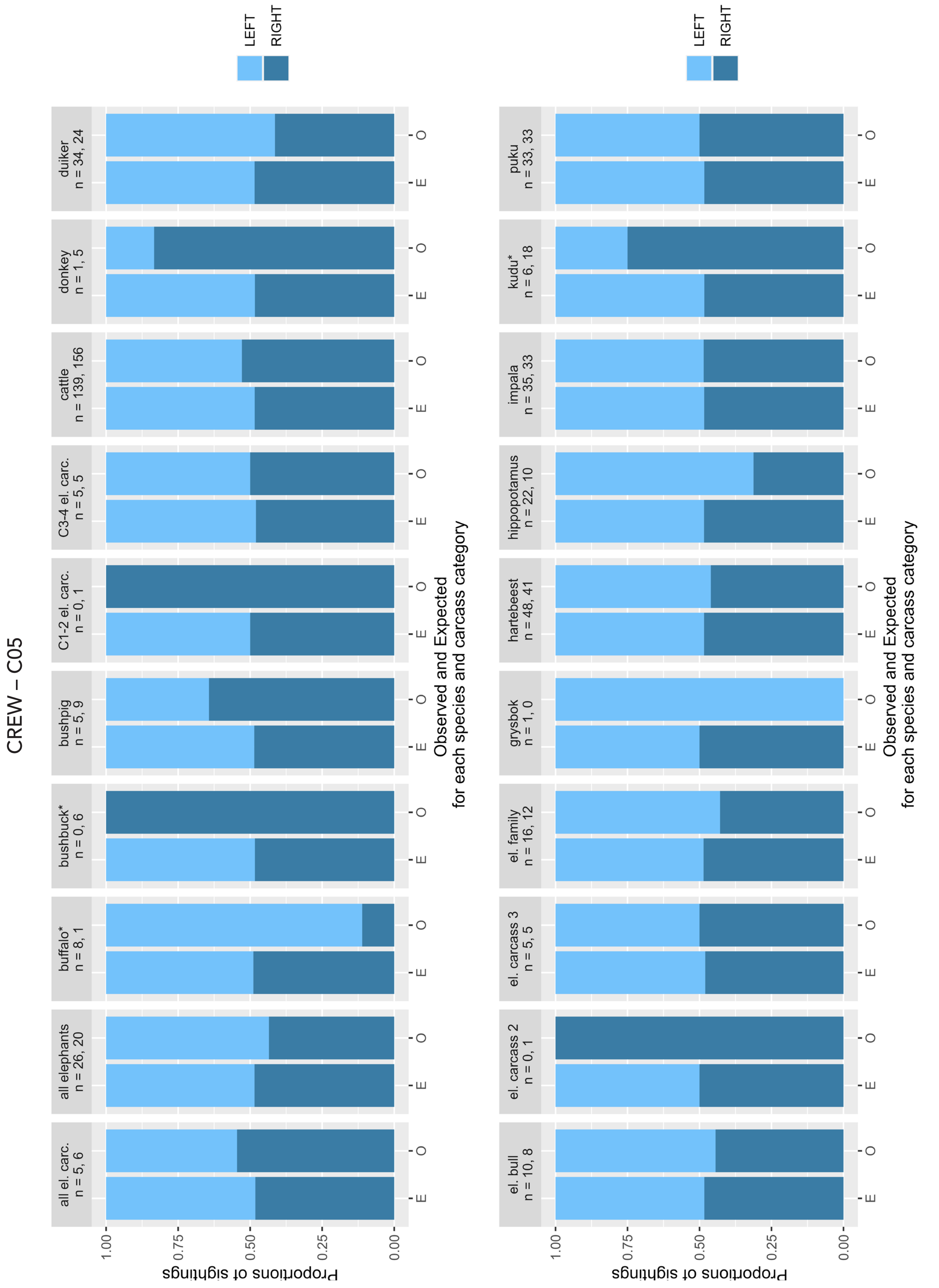

CREW – C02
horse n = 13, 13
impala* n = 194, 142
klipspringer n = 1, 0
kudu n = 84, 59
oryx* n = 12, 3
ostrich n = 49, 35
red lechwe* n = 344, 274
reedbuck n = 18, 16
roan* n = 26, 11
shoat* n = 46, 25
sitatunga n = 8, 4
tsessebe n = 32, 26
warthog n = 73, 67
waterbuck n = 12, 13
wildebeest n = 28, 31
zebra* n = 133, 81
E
O
LEFT
RIGHT
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
Observed and Expected
for each species and carcass category

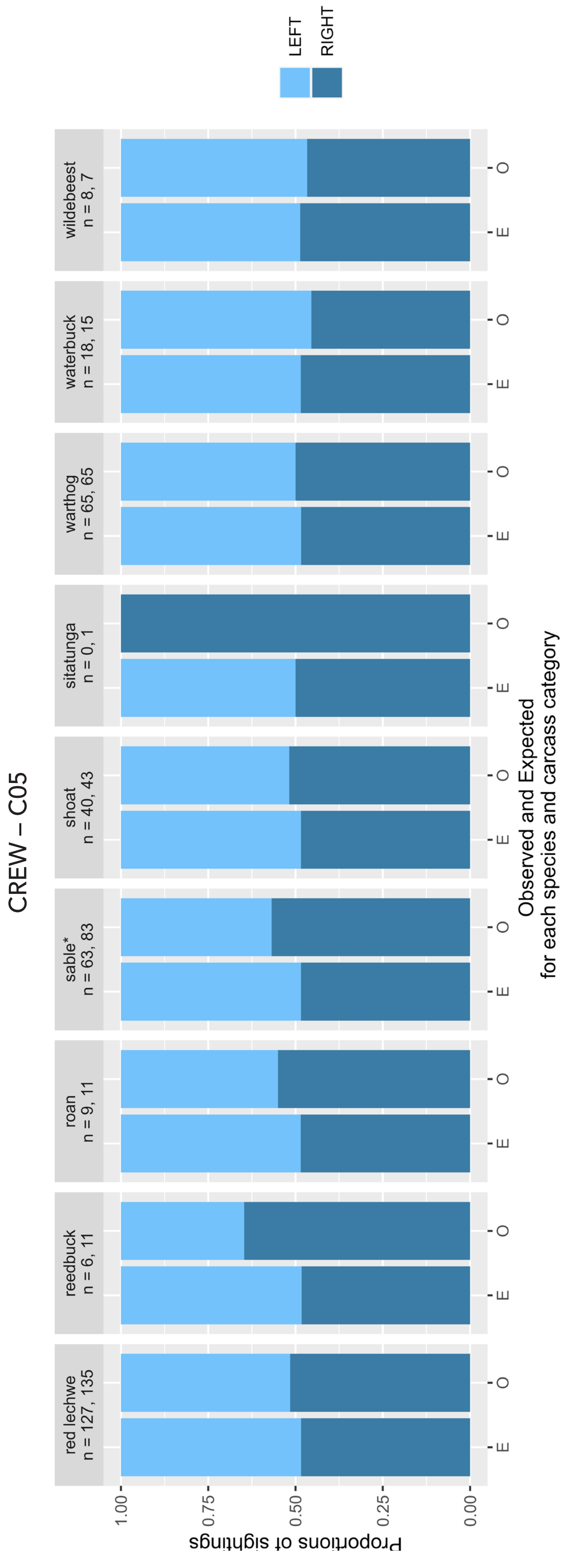

CREW – C03
LEFT
RIGHT
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
all el. carc.* n = 125, 232
all elephants n = 424, 388
baboon n = 1, 4
buffalo n = 39, 34
bushbuck n = 0, 1
bushpig n = 1, 3
C1-2 el. carc. n = 0, 3
C3-4 el. carc.* n = 125, 229
cattle* n = 174, 257
donkey* n = 48, 70
Observed and Expected for each species and carcass category
duiker* n = 3, 29
el. bull n = 189, 170
el. carcass 1 n = 0, 1
el. carcass 2 n = 0, 2
el. carcass 3* n = 70, 127
el. carcass 4* n = 55, 102
el. family n = 235, 218
giraffe n = 58, 59
hippopotamus* n = 51, 89
horse n = 4, 9
Observed and Expected for each species and carcass category

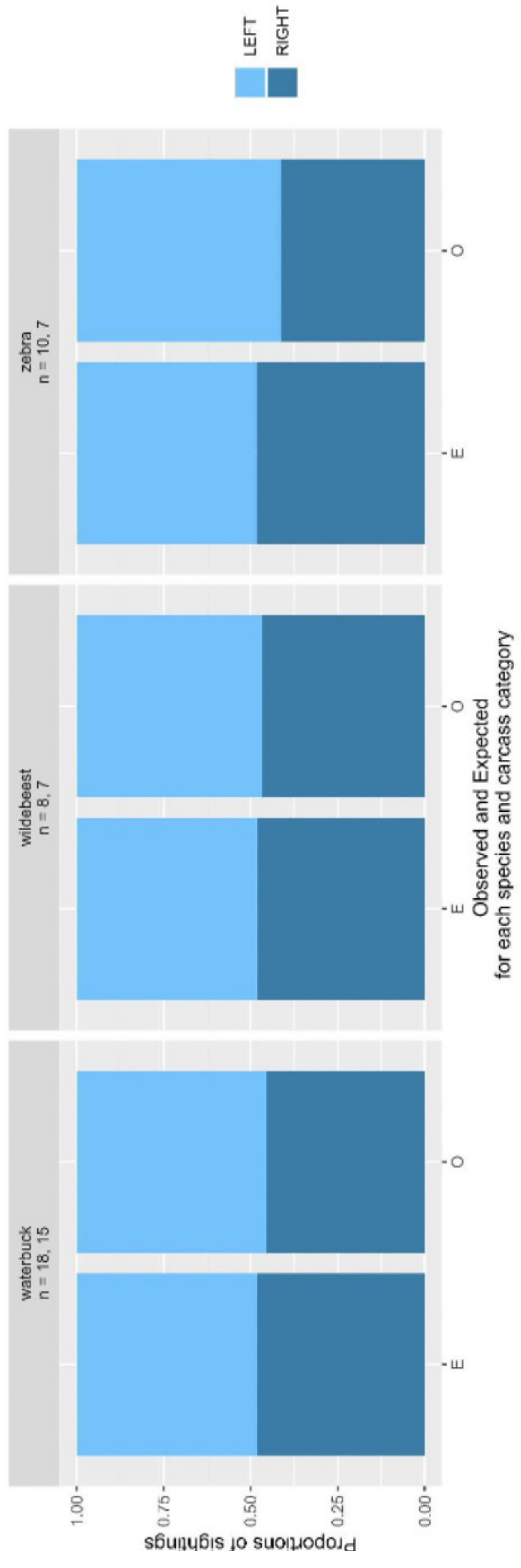

CREW – C03
impala*
n = 35, 77
kudu*
n = 19, 47
oryx
n = 4, 5
ostrich
n = 17, 14
red lechwe*
n = 179, 306
reedbuck
n = 23, 27
roan*
n = 2, 9
sable*
n = 9, 20
shoat*
n = 15, 39
springbok
n = 0, 1
tsessebe
n = 10, 14
warthog*
n = 25, 56
waterbuck*
n = 9, 23
wildebeest
n = 3, 7
zebra
n = 75, 82
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category
LEFT
RIGHT

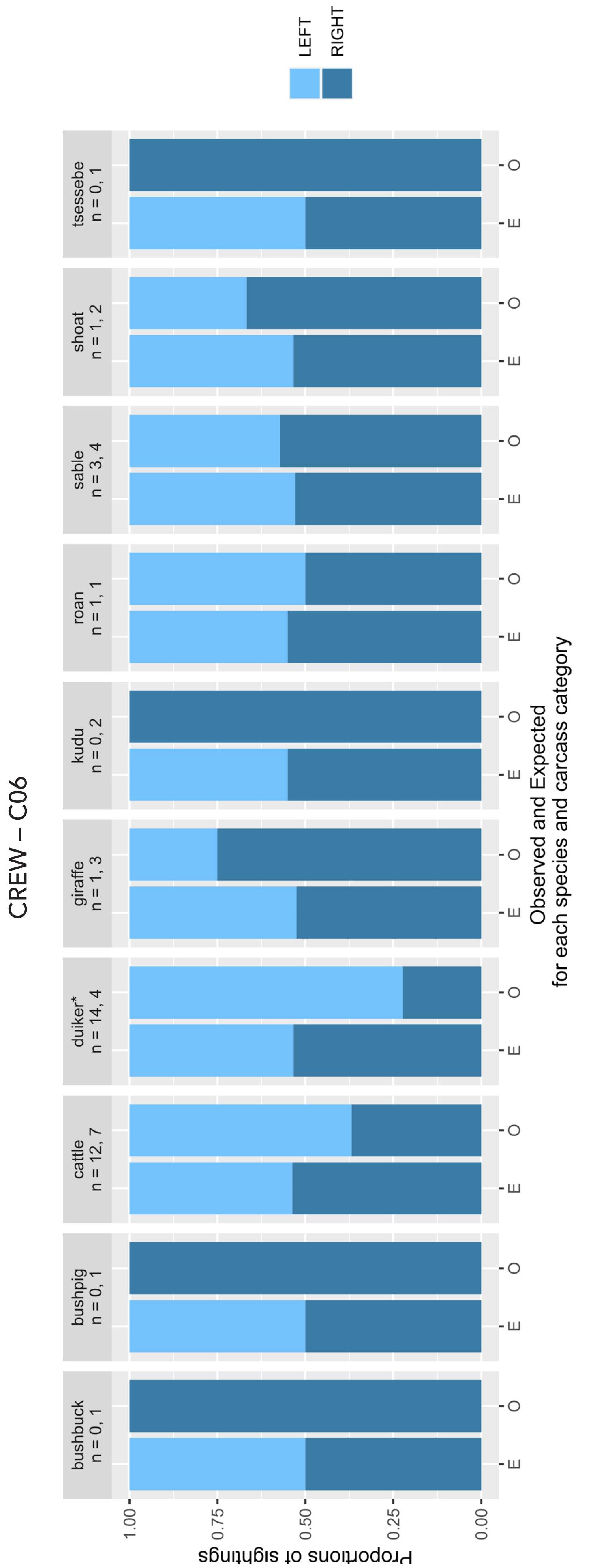

CREW – C04
all el. carc.*
n = 81, 122
all elephants
n = 143, 169
baboon
n = 1, 3
buffalo
n = 41, 36
bushbuck
n = 0, 3
bushpig
n = 0, 2
C1-2 el. carc.*
n = 5, 30
C3-4 el. carc.
n = 76, 92
cattle*
n = 54, 80
donkey
n = 4, 6
duiker
n = 29, 41
el. bull
n = 62, 53
el. carcass 1
n = 2, 2
el. carcass 2*
n = 3, 28
el. carcass 3*
n = 24, 42
el. carcass 4
n = 52, 50
el. family*
n = 81, 116
giraffe
n = 17, 21
grysbok*
n = 0, 6
hippopotamus
n = 23, 27
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category
LEFT
RIGHT

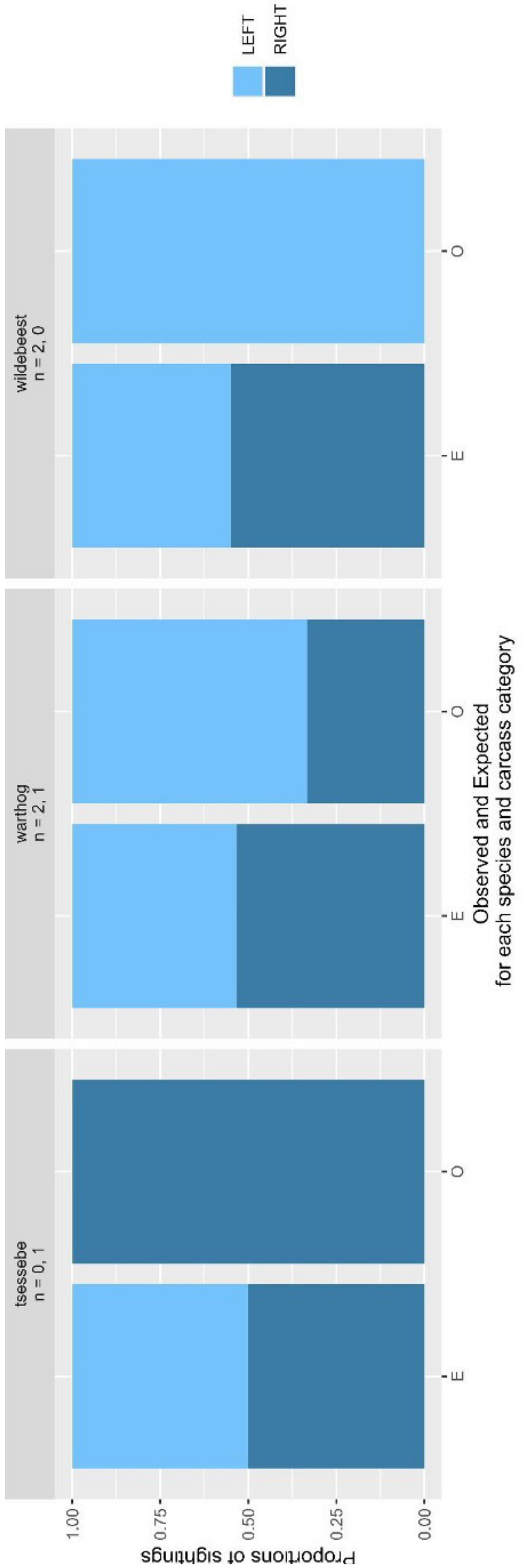

CREW – C04
horse*
n = 0, 4
impala*
n = 8, 30
kudu
n = 23, 25
oryx
n = 3, 1
ostrich
n = 10, 13
puku*
n = 0, 7
red lechwe
n = 55, 77
reedbuck
n = 5, 12
roan
n = 6, 8
shoat
n = 3, 7
sitatunga
n = 1, 1
springbok
n = 1, 0
tsessebe
n = 2, 2
warthog*
n = 25, 47
waterbuck*
n = 0, 7
wildebeest*
n = 7, 17
zebra
n = 23, 35
E
O
1.00
0.75
0.50
0.25
0.00
Proportions of sightings
Observed and Expected
for each species and carcass category
LEFT
RIGHT

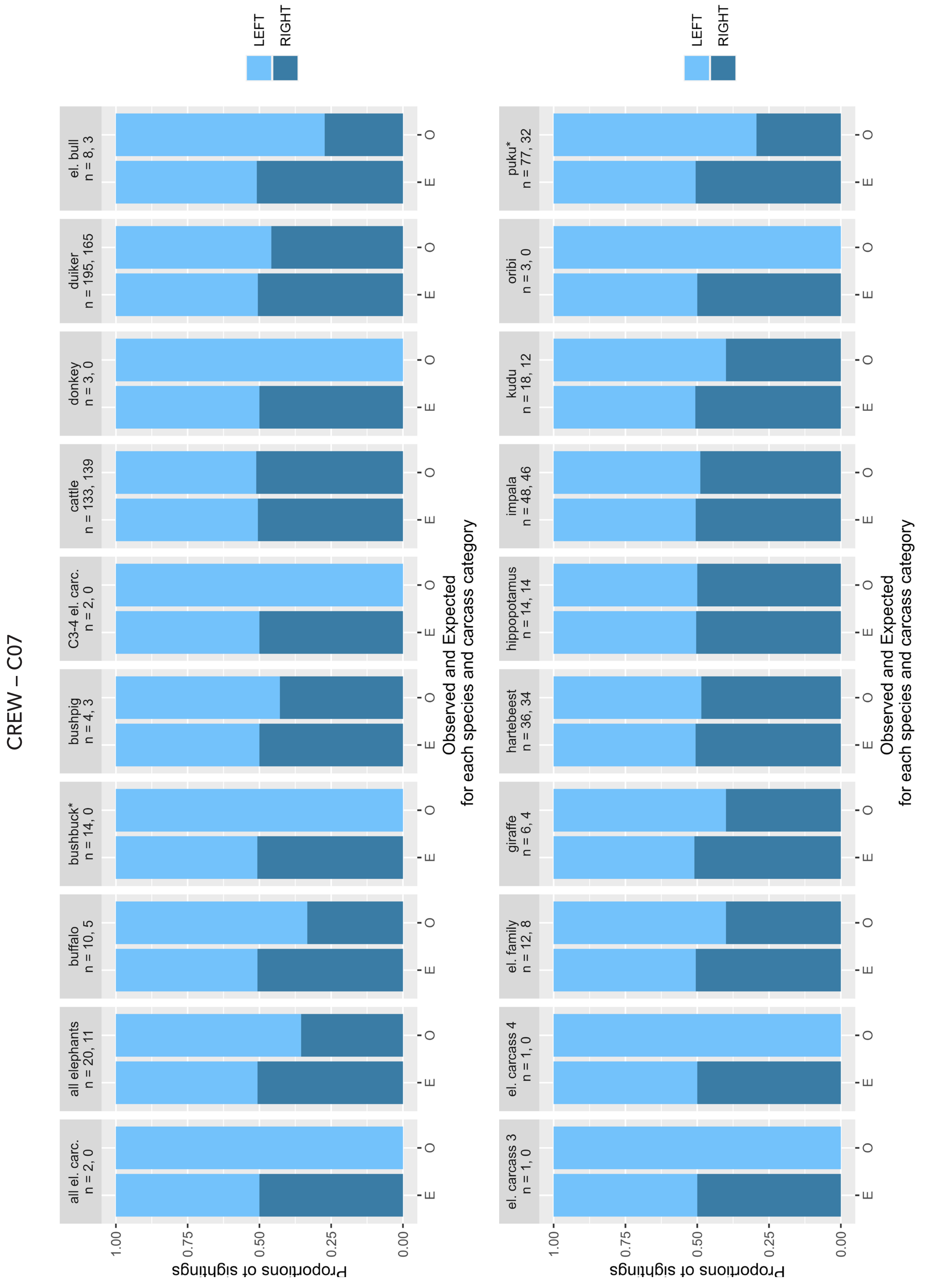

CREW – C05
LEFT
RIGHT
all el. carc.
n = 5, 6
all elephants
n = 26, 20
buffalo*
n = 8, 1
bushbuck*
n = 0, 6
bushpig
n = 5, 9
C1-2 el. carc.
n = 0, 1
C3-4 el. carc.
n = 5, 5
cattle
n = 139, 156
donkey
n = 1, 5
duiker
n = 34, 24
el. bull
n = 10, 8
el. carcass 2
n = 0, 1
el. carcass 3
n = 5, 5
el. family
n = 16, 12
grysbok
n = 1, 0
hartebeest
n = 48, 41
hippopotamus
n = 22, 10
impala
n = 35, 33
kudu*
n = 6, 18
puku
n = 33, 33
E
O
1.00
0.75
0.50
0.25
0.00
Proportions of sightings
Observed and Expected
for each species and carcass category


CREW – C05
red lechwe n = 127, 135
reedbuck n = 6, 11
roan n = 9, 11
sable* n = 63, 83
shoat n = 40, 43
sitatunga n = 0, 1
warthog n = 65, 65
waterbuck n = 18, 15
wildebeest n = 8, 7
E
O
1.00
0.75
0.50
0.25
0.00
Proportions of sightings
Observed and Expected for each species and carcass category
LEFT
RIGHT

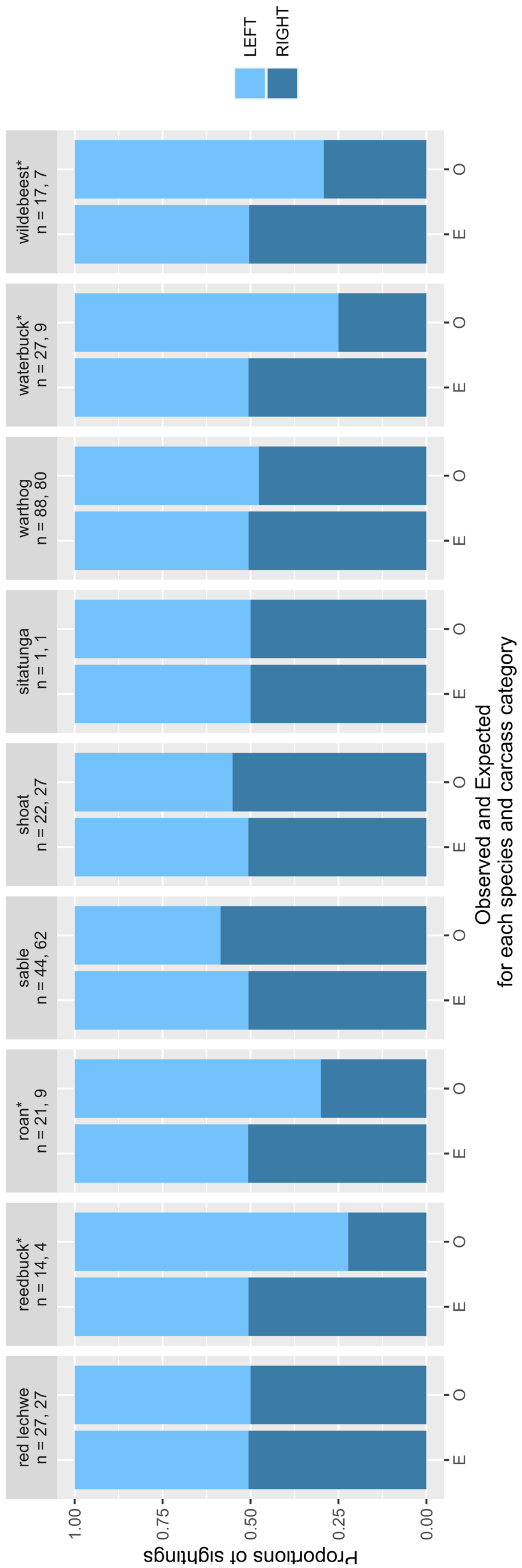

waterbuck n = 18, 15
wildebeest n = 8, 7
zebra n = 10, 7
E
O
1.00
0.75
0.50
0.25
0.00
Proportions of sightings
Observed and Expected for each species and carcass category
LEFT
RIGHT

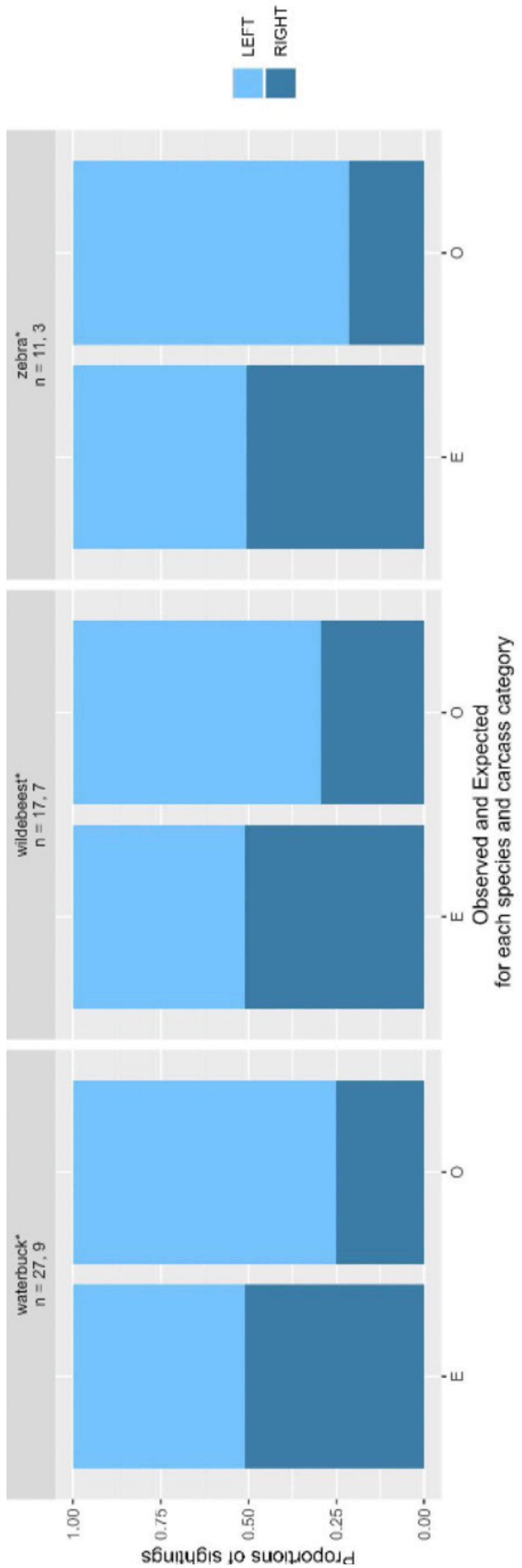

CREW – C06
bushbuck
n = 0, 1
bushpig
n = 0, 1
cattle
n = 12, 7
duiker*
n = 14, 4
giraffe
n = 1, 3
kudu
n = 0, 2
roan
n = 1, 1
sable
n = 3, 4
shoat
n = 1, 2
tsessebe
n = 0, 1
LEFT
RIGHT
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category

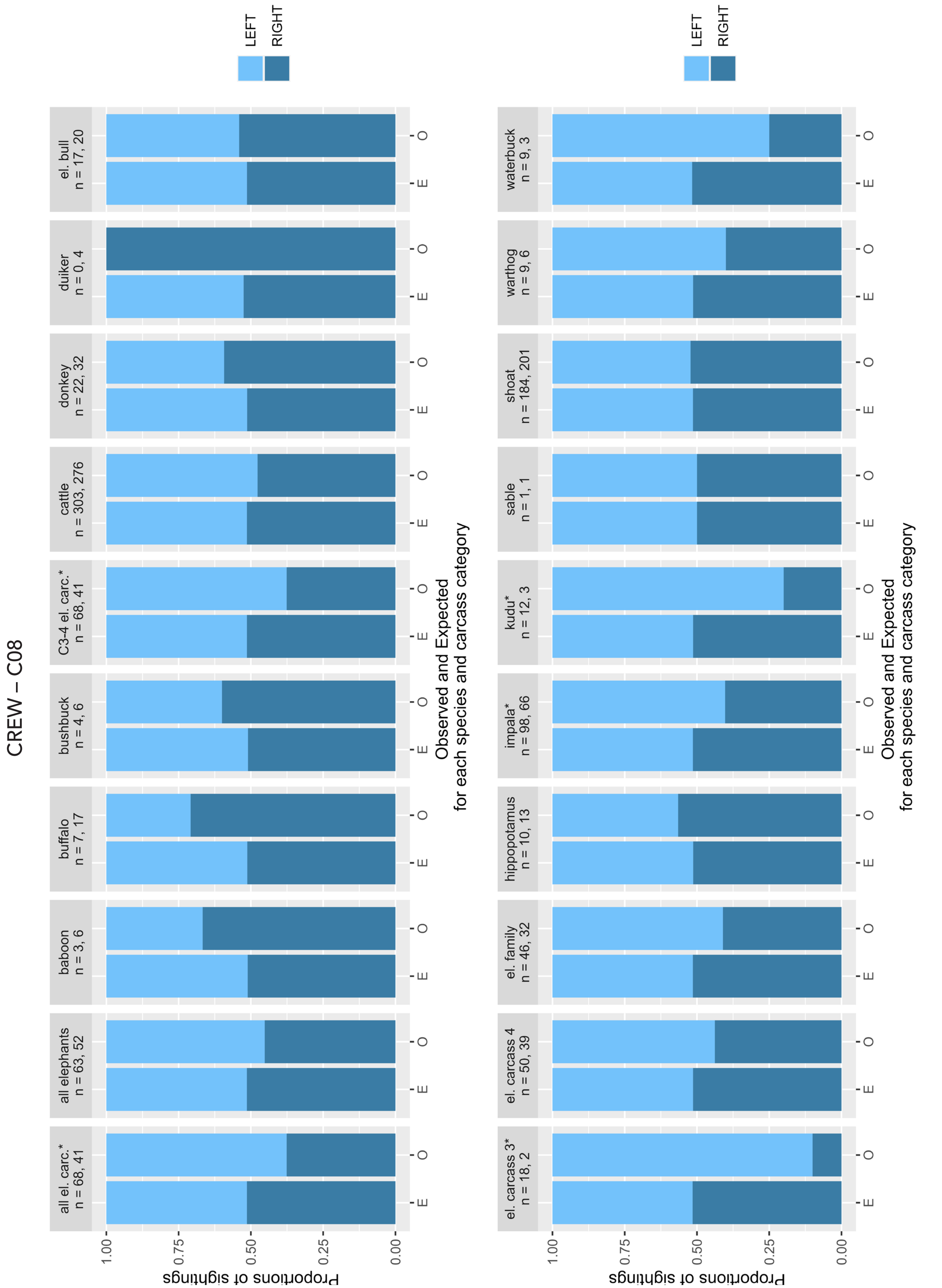

tsessebe
n = 0, 1
warthog
n = 2, 1
wildebeest
n = 2, 0
LEFT
RIGHT
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category

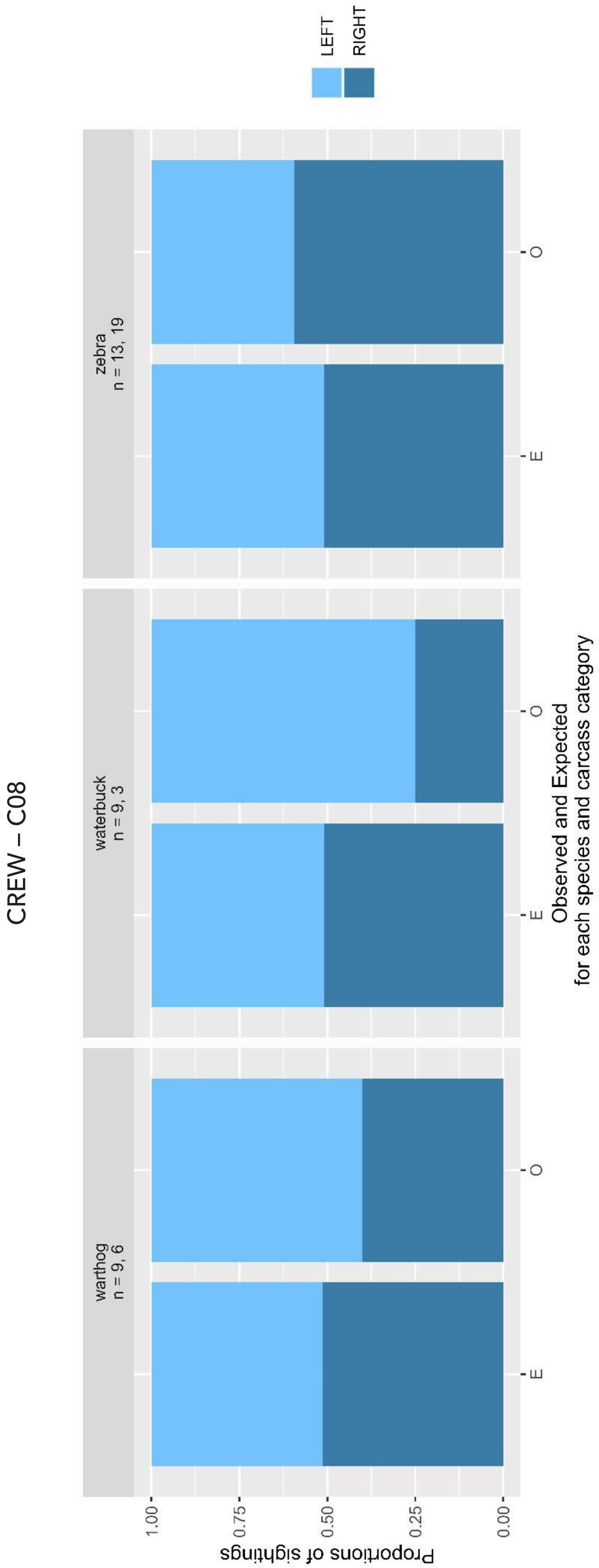

CREW – C07
all el. carc. n = 2, 0
all elephants n = 20, 11
buffalo n = 10, 5
bushbuck* n = 14, 0
bushpig n = 4, 3
C3-4 el. carc. n = 2, 0
cattle n = 133, 139
donkey n = 3, 0
duiker n = 195, 165
el. bull n = 8, 3
el. carcass 3 n = 1, 0
el. carcass 4 n = 1, 0
el. family n = 12, 8
giraffe n = 6, 4
hartebeest n = 36, 34
hippopotamus n = 14, 14
impala n = 48, 46
kudu n = 18, 12
oribi n = 3, 0
puku* n = 77, 32
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected for each species and carcass category
LEFT
RIGHT

CREW – C07


LEFT
RIGHT
red lechwe
n = 27, 27
reedbuck*
n = 14, 4
roan*
n = 21, 9
sable
n = 44, 62
shoat
n = 22, 27
sitatunga
n = 1, 1
warthog
n = 88, 80
waterbuck*
n = 27, 9
wildebeest*
n = 17, 7
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category


LEFT
RIGHT
waterbuck*
n = 27, 9
wildebeest*
n = 17, 7
zebra*
n = 11, 3
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category


CREW – C08
LEFT
RIGHT
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
all el. carc.* n = 68, 41
all elephants n = 63, 52
baboon n = 3, 6
buffalo n = 7, 17
bushbuck n = 4, 6
C3-4 el. carc.* n = 68, 41
cattle n = 303, 276
donkey n = 22, 32
duiker n = 0, 4
el. bull n = 17, 20
Observed and Expected for each species and carcass category
el. carcass 3* n = 18, 2
el. carcass 4 n = 50, 39
el. family n = 46, 32
hippopotamus n = 10, 13
impala* n = 98, 66
kudu* n = 12, 3
sable n = 1, 1
shoat n = 184, 201
warthog n = 9, 6
waterbuck n = 9, 3
Observed and Expected for each species and carcass category

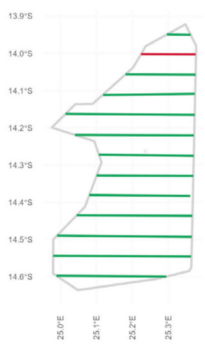

CREW – C08
warthog
n = 9, 6
waterbuck
n = 9, 3
zebra
n = 13, 19
LEFT
RIGHT
Proportions of sightings
1.00
0.75
0.50
0.25
0.00
E
O
Observed and Expected
for each species and carcass category

Appendix 13: Cartography of mean height and speed target adherence on transect

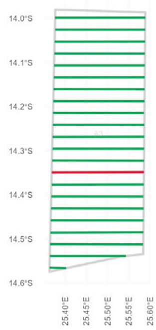
Mean height on transect - map alert

Mean speed on transect - map alert

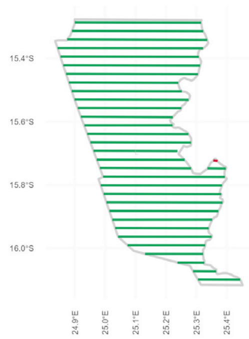
K - P04 - Mean Speed Check



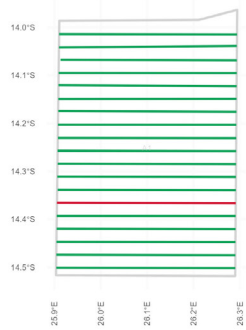
A3 - P04 - Mean Speed Check



L - P07 - Mean Speed Check

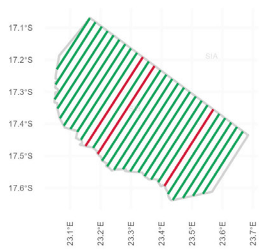


A1 - P05 - Mean Speed Check

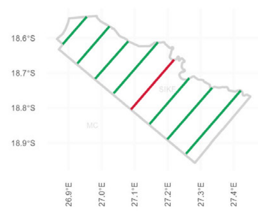


Q2 - P05 - Mean Speed Check

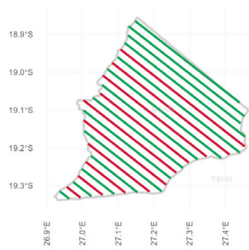
SIB - P05 - Mean Speed Check



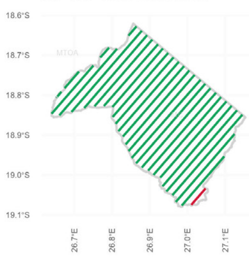
SIKF - P03 - Mean Speed Check



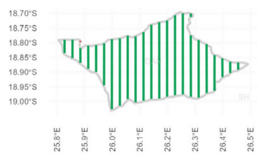
NGAM - P03 - Mean Speed Check



MC - P03 - Mean Speed Check

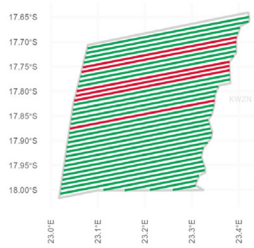


DAN - P03 - Mean Speed Check

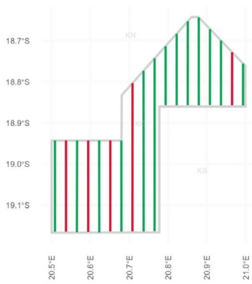


ZNP - P03 - Mean Speed Check

SUS - P03,P02,P01 - Mean Speed Check

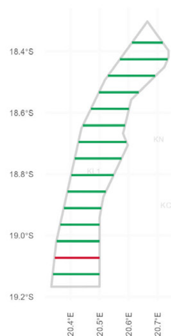


KC - P03 - Mean Speed Check

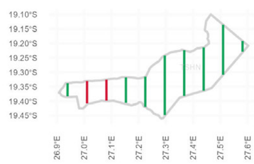


MOE - P02 - Mean Speed Check

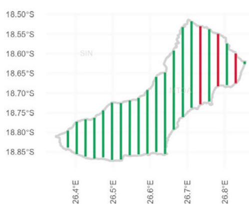
KL1 - P02 - Mean Speed Check



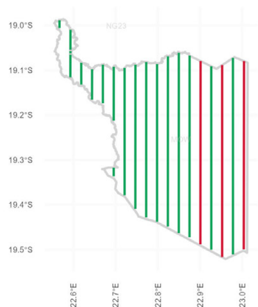
TSHN - P01 - Mean Speed Check



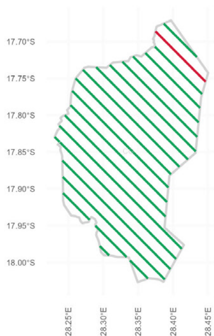
MTOA - P01 - Mean Speed Check



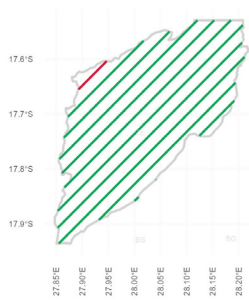
MOW - P01 - Mean Speed Check



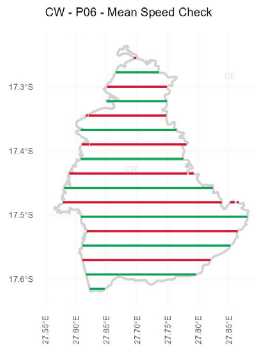
CG - P06 - Mean Speed Check

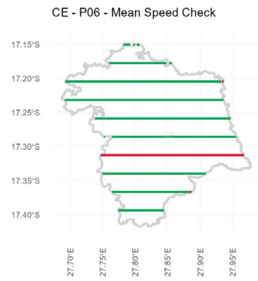


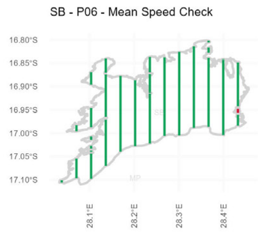
ZE - P06 - Mean Speed Check

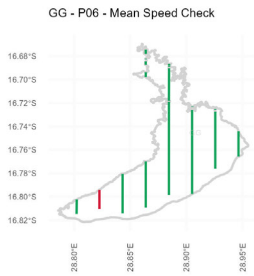


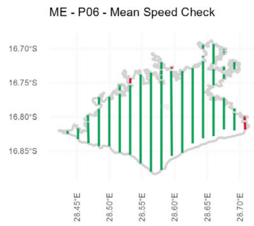

SJ - P06 - Mean Speed Check

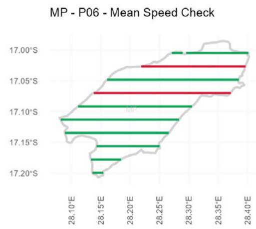

CW - P06 - Mean Speed Check

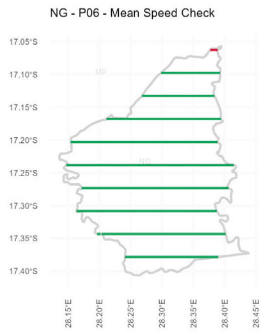

CE - P06 - Mean Speed Check

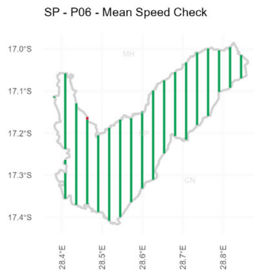

SB - P06 - Mean Speed Check


GG - P06 - Mean Speed Check


ME - P06 - Mean Speed Check

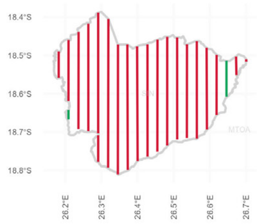

MP - P06 - Mean Speed Check


NG - P06 - Mean Speed Check


SP - P06 - Mean Speed Check

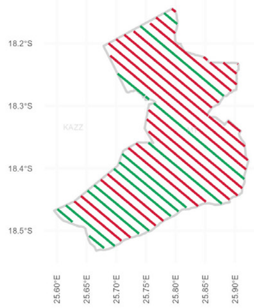
Standard deviation of height on transect - map alert

SIN - P02 - SD Height Check

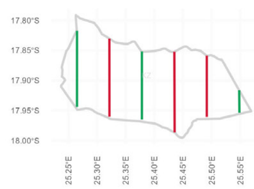


KAZZ - P02 - SD Height Check

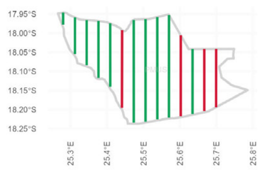
MT - P02,P01 - SD Height Check



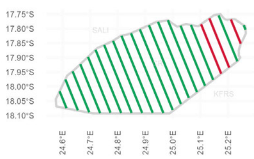
KZ - P02 - SD Height Check



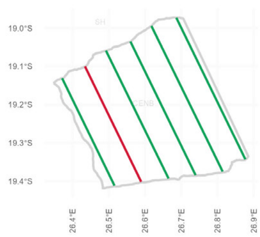
PMUS - P02 - SD Height Check



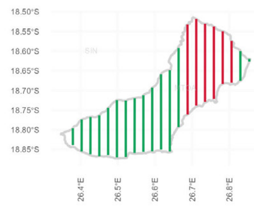
CR - P02 - SD Height Check



CENB - P01 - SD Height Check

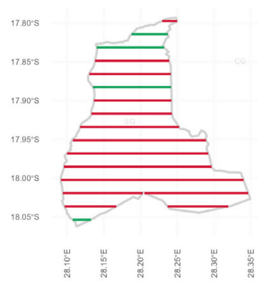


MTOA - P01 - SD Height Check

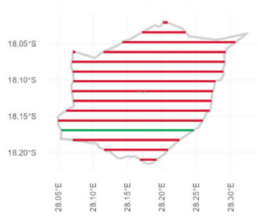


ROB - P01 - SD Height Check

SG - P06 - SD Height Check

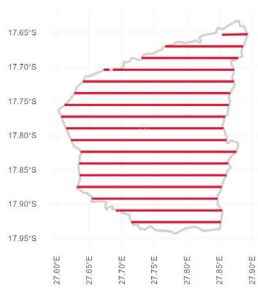


RA - P06 - SD Height Check

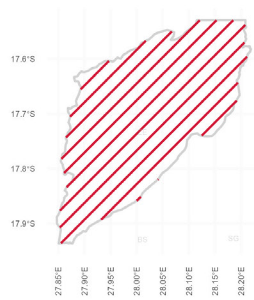


BS - P06 - SD Height Check

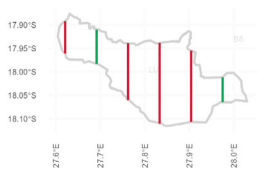
ZW - P06 - SD Height Check



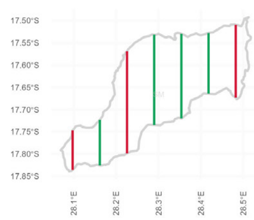
ZE - P06 - SD Height Check



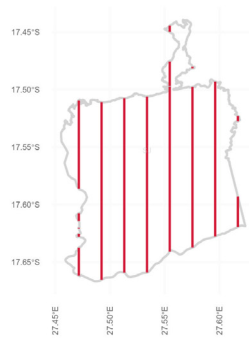
LU - P06 - SD Height Check



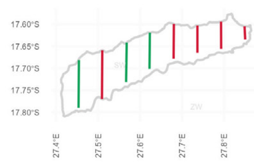
SM - P06 - SD Height Check



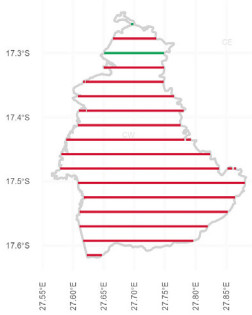
SJ - P06 - SD Height Check



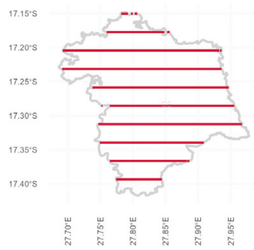
SW - P06 - SD Height Check



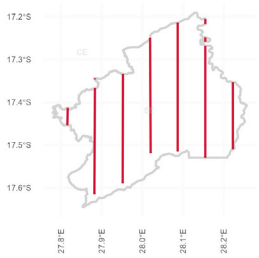
CW - P06 - SD Height Check



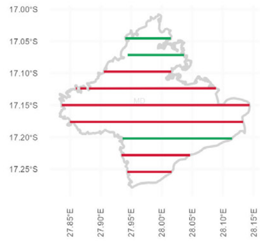
CE - P06 - SD Height Check



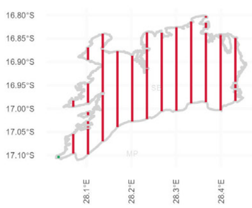
SE - P06 - SD Height Check



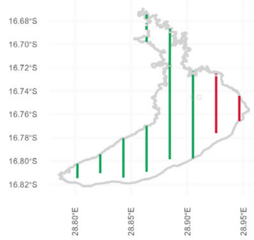
MD - P06 - SD Height Check



SB - P06 - SD Height Check



GG - P06 - SD Height Check



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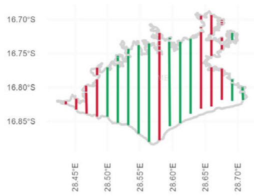

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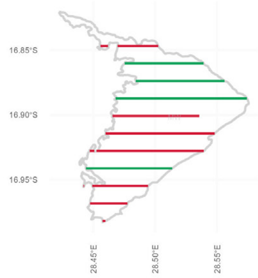

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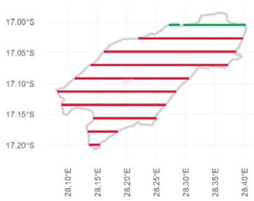

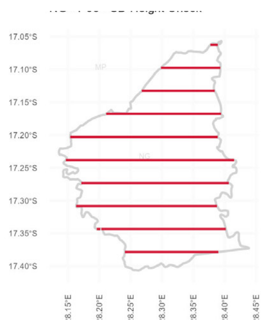

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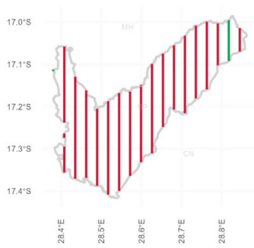
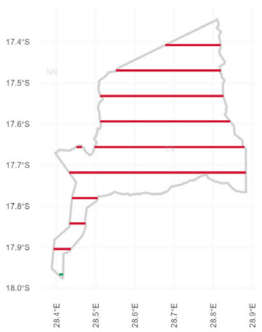
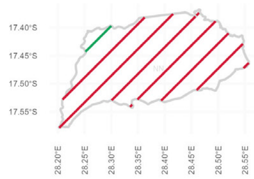


CS - P06 - SD Height Check

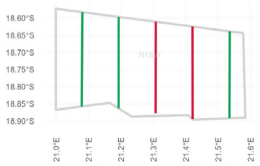


NN - P06 - SD Height Check

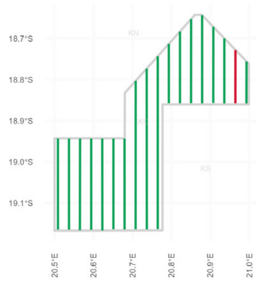


Standard deviation of speed on transect - map alert

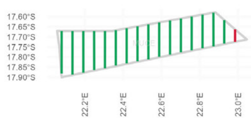
N1SW - P03 - SD Speed Check



KC - P03 - SD Speed Check

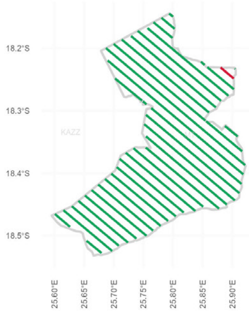


MUCE - P03 - SD Speed Check

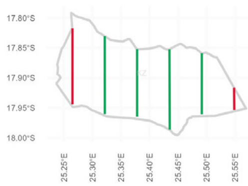


SIN - P02 - SD Speed Check

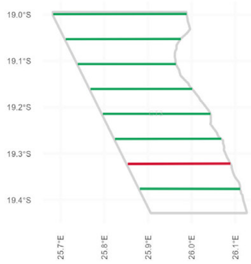
MT - P02 - SD Speed Check



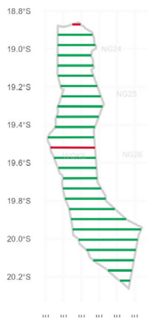
KZ - P02 - SD Speed Check



CT3 - P02 - SD Speed Check



NG40 - P02 - SD Speed Check



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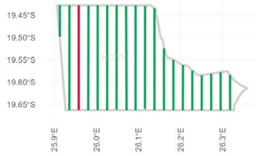
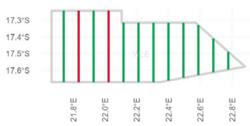
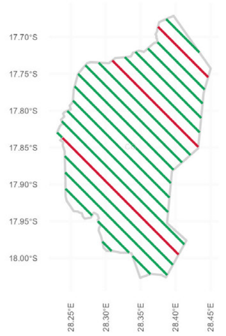


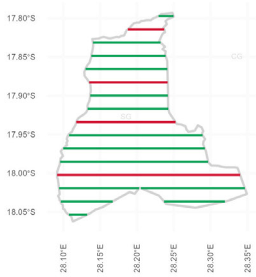
WLE - P01 - SD Speed Check



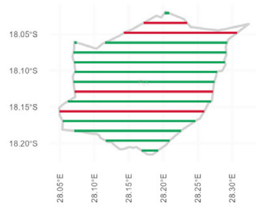
CG - P06 - SD Speed Check



SG - P06 - SD Speed Check



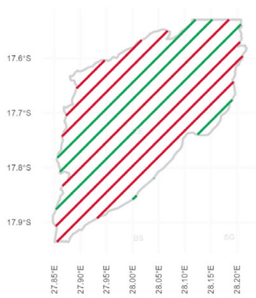
RA - P06 - SD Speed Check



BS - P06 - SD Speed Check

ZW - P06 - SD Speed Check

ZE - P06 - SD Speed Check



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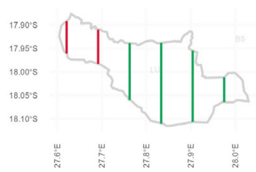

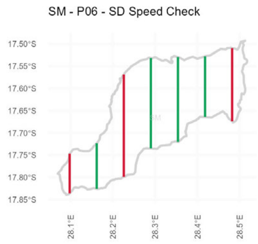
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17.50°S
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17.60°S
17.65°S
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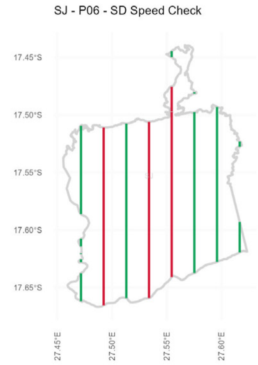
17.80°S
17.85°S
28.1°E
28.2°E
28.3°E
28.4°E
28.5°E


SJ - P06 - SD Speed Check
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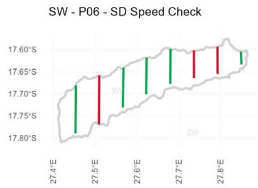
27.60°E


SW - P06 - SD Speed Check
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17.75°S
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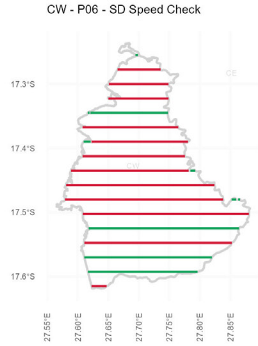
27.5°E
27.6°E
27.7°E
27.8°E


CW - P06 - SD Speed Check
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17.4°S
17.5°S
17.6°S
27.55°E
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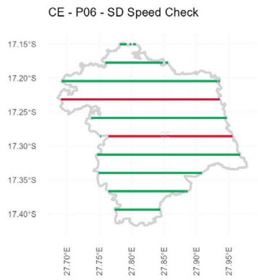
27.65°E
27.70°E
27.75°E
27.80°E
27.85°E


CE - P06 - SD Speed Check
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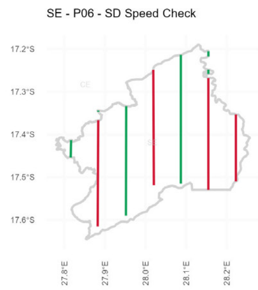
27.90°E
27.95°E


SE - P06 - SD Speed Check
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17.5°S
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27.9°E
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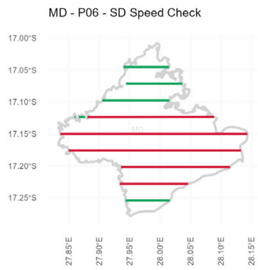
28.2°E


MD - P06 - SD Speed Check
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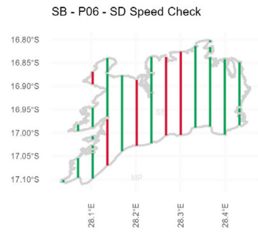
28.10°E
28.15°E


SB - P06 - SD Speed Check
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28.2°E
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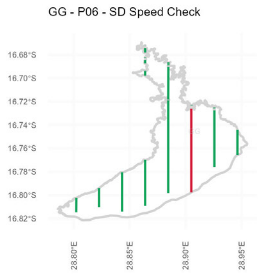
28.4°E


GG - P06 - SD Speed Check
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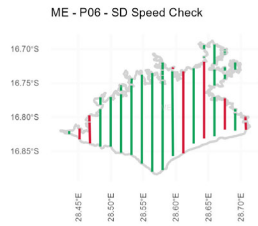
ME - P06 - SD Speed Check
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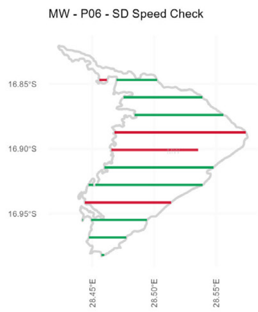
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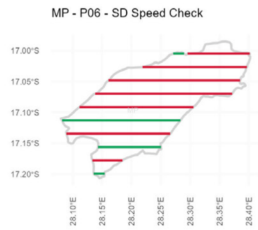
28.55°E


MP - P06 - SD Speed Check
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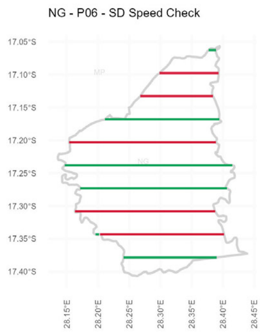
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17.25°S
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17.35°S
17.40°S
28.15°E
28.20°E
28.25°E
28.30°E
28.35°E
28.40°E
28.45°E


SP - P06 - SD Speed Check
17.0°S
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17.3°S
17.4°S
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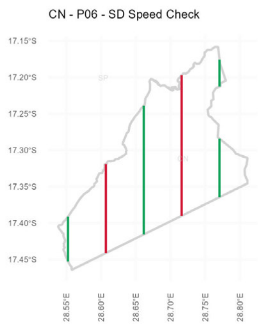
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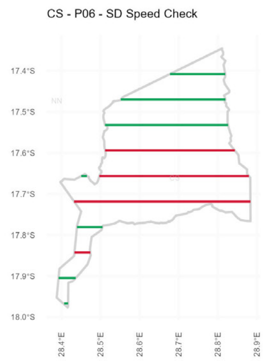
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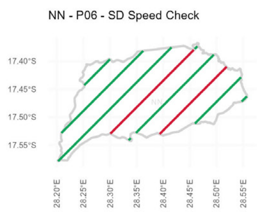
NN - P06 - SD Speed Check
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28.30°E
28.35°E
28.40°E
28.45°E
28.50°E
28.55°E

Appendix 14: Lessons learnt

The KAZA Elephant Survey (2022) provided valuable lessons that can guide the planning and implementation of future surveys. In this section we note some of the lessons learnt.

1. Timing and project cycle

The compressed timeframe for preparing for the survey was the most critical factor in the challenges we faced. To avoid such challenges, it is recommended that the coordination planning phase begins no later than October of the year before the survey. Initially, the coordinator should be engaged on an ad-hoc basis, with full-time engagement required from February or March until the end of the survey. Tenders for service providers must be advertised in January of the survey year, along with a project announcement, to improve online visibility. This should be done early in the project cycle to allow for sufficient time to finalise aircraft and pilot details required to apply for overflight and landing permits.

2. Selection of service providers

When selecting service providers for the survey, it is important to prioritise qualities such as a collaborative spirit and adaptability in the experts being recruited. Before finalising contracts with the chosen service provider, it is recommended that more effort is put into due diligence, which may include an inspection visit to view the contractor's aircraft and documentation. Ideally, service providers supplying aircraft and pilots only should be contracted. Other important roles should be recruited separately by the coordination team in a training and evaluation workshop. It is generally easier to use in-country operators as this would streamline the permitting process. If this is not possible, obtaining permits for foreign registered aircraft may be more complicated.

3. Crew selection

It is important to put more emphasis on calibration when selecting observers. Every crew role is crucial, so a selection process should be applied to all positions. It is also recommended that individuals selected by contractors undergo the same selection process and be considered candidates rather than confirmed staff.

4. Training and evaluation

When planning a training and evaluation workshop, it is important to allocate a dedicated team and allow sufficient time for organisation and travel arrangements. Completing modules, including flying exercises, should also be given ample time. Combining training and evaluation for many survey participants in the same workshop can be challenging. It may be best to evaluate a large pool of participants based on non-flying criteria before allowing the best candidates to participate in flight training, giving them more time to train. Ideally, training and evaluation should take place well in advance of the survey, either at the end of the preceding year or early in the survey year (e.g., March).

Capacity building objectives should not be squeezed into the evaluation and selection workshop unless sufficient capacity exists to do both. That said, capacity development for future surveys is critical, particularly for front and rear seat observers.

5. Logistics and coordination

Logistics and coordination are vital, and it is advisable to start planning in October of the year before and engage the coordinator over a more extended period on an ad hoc basis. Obtaining overflight permits should be done as early as possible, following the selection of service providers to obtain details of the participating aircraft and pilots. The process of obtaining official KAZA supporting letters could also be improved.

Flying should begin earlier in August, and in Botswana, using four aircraft working in pairs would be preferable. This would allow for a morning-only flight schedule and provide time in the afternoons for photo interpretation.

To ensure efficient coordination and training, crews should not all start at the same time. Instead, the coordination team should spend valuable time with each team to provide refresher training, review the operations manual and standards, and establish a routine. It is also recommended to operate out of fewer bases with stable electricity and better living and working conditions.

Clear hierarchy structures should be established to ensure everyone understands their roles and responsibilities. Specific people should oversee scrutinising the data, and planned meetings should be held to discuss the results as a team in daily briefings. Good communication between crews, data managers and the ops room should be maintained throughout the survey.

6. Calibration

Calibration is essential, and it is recommended to plan the survey around the calibration needs rather than the other way around. Calibration training exercises should be carried out as part of the crew selection process, and actual calibration results triple-checked. The responsibility for checking the calibration results should be assigned to one (or more) person(s) in a clear way, to avoid a situation where all experts trust each other and do not take the necessary time to explore the data in depth. Furthermore, a protocol for conducting calibration throughout the survey should be established.

7. Survey design

The survey design could benefit from certain modifications of strata to avoid 1) the need for multiple flight sessions to complete a stratum, and 2) having broken transect segments due to stratum shape. Strata should also be modified to account for elephant density based on the latest available information. Such changes must be done timeously, and the survey design should be finalised at least one month before the launch, with GIS files shared among the team. Avoid changing strata shape during the survey. If time and resources permit, it is possible and perhaps advisable to choose higher sampling intensities than those calculated to achieve the objectives set at the KAZA TFCA scale, to provide more accurate results for geographical sub-units of particular interest (e.g., Angola).

8. National Coordination

Given the limited pool of expertise and experience available for conducting surveys, it may not be feasible to synchronize national elephant population surveys with the KAZA survey, although it would be ideal. Nevertheless, as the KAZA TFCA is home to significant proportions of the national elephant populations of the partner states, it is still worth considering this option despite the challenges it presents, including competition for limited human resources. An alternative approach would be to conduct the survey of areas outside KAZA in the year preceding the KAZA-wide survey so that it aligns with the reporting cycle of the AESR.

9. Modernising Wildlife Surveys

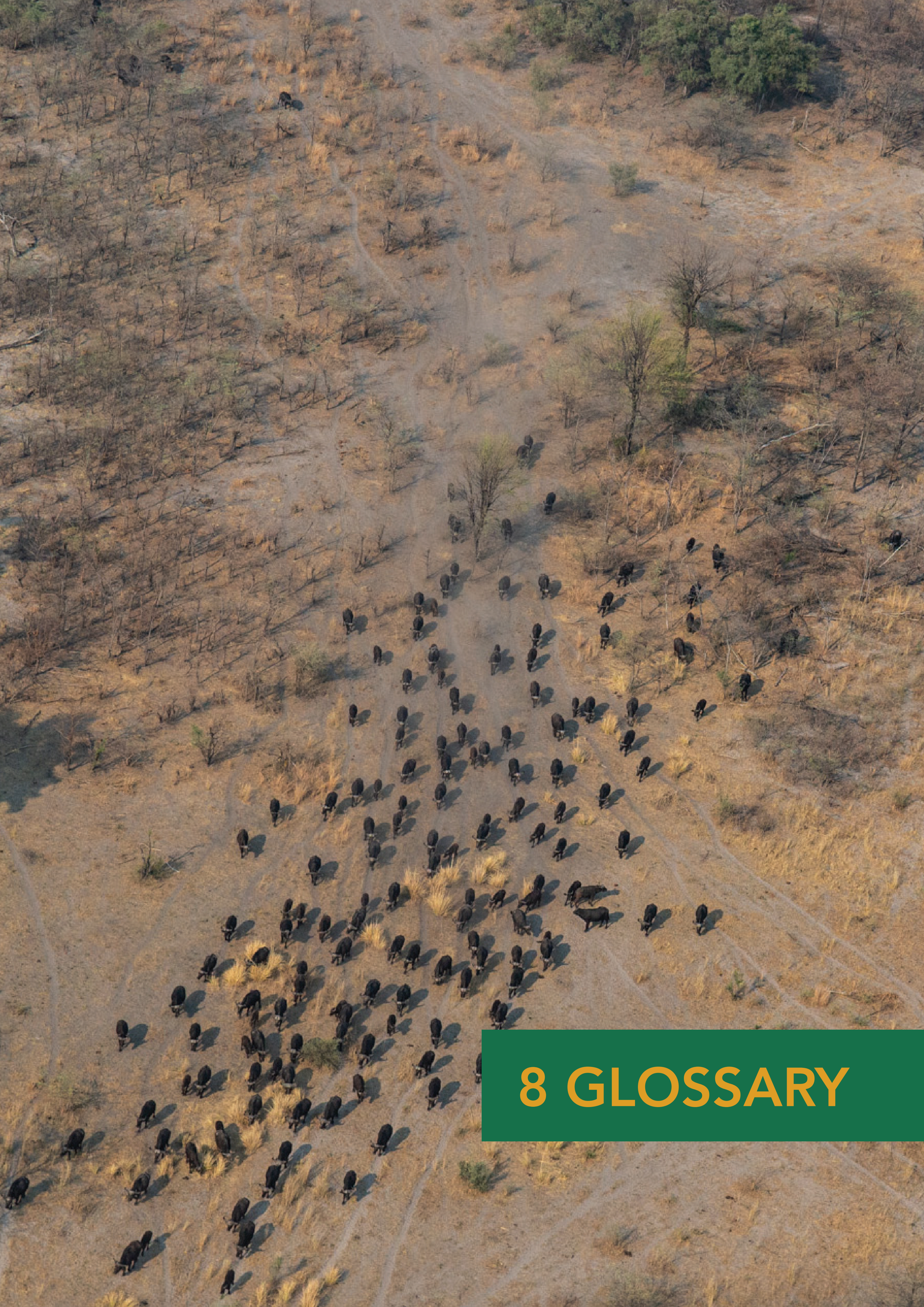
The latest iteration of external cameras should be used for the next survey, with no legal barriers to attaching the cameras to the aircraft. This work should have a dedicated team leader and staffing, with a sufficient budget. Deeper integration of these systems and methods is encouraged, rather than it being a "stand-alone" experiment.

10. Data management

When managing survey data, it is important to custom design tools and ensure that data managers are trained to use them prior to the start of the survey. It is also highly recommended to use an application-based digital capture tool instead of paper.

11. Media and communication

To ensure effective communication and media coverage during the survey, it is important to include an appropriate media budget in the planning process. In addition, it is recommended to have a communications team and strategy in place 8-12 months in advance to ensure adequate time for planning and implementation. This will enable the team to identify the target audience, develop communication materials, and establish relationships with key stakeholders to ensure that information is disseminated effectively. By prioritising communication and media, the survey team can ensure that their efforts are well-publicised, and that the survey's goals and findings are communicated effectively to a wider audience.



8 GLOSSARY

8. Glossary

Accuracy - refers to the level of systematic error, or bias, in a survey. It is the degree to which a population estimate aligns with the actual number. If the population estimate is close to the true population number, it is an accurate estimate. This should not be confused with *precision*.

Baseline - is straight line that is perpendicular to the orientation of *transects* and extends the entire length of the *stratum*.

Block Survey - is a variant of *sample survey* in which the sampling units are referred to as *blocks*.

Block - a sampling unit used in a *block survey*. These blocks can have various shapes and are delineated on the ground using physical features such as roads, rivers, or watersheds.

Carcass Category 1 - refers to a fresh elephant carcass, distinguished by its flesh intact, giving the body a rounded appearance. At this stage, vultures are likely to be present, and the ground remains moist from body fluids.

Carcass Category 2 - refers to a recent elephant carcass, distinguished by the presence of a rot patch. Skin is still likely present, and the skeleton remains intact and is not scattered.

Carcass Category 3 - refers to an old elephant carcass, distinguished by the absence of a rot patch (where decomposition occurred vegetation has regrown) The bones are scattered, and skin is usually absent.

Carcass Category 4 - refers to a very old elephant carcass, distinguished by scattered bones that are turning grey.

Multi-Flight Stratum - is a large *stratum* that cannot be surveyed in a single flight session due to its size. Instead, it requires multiple flight sessions to cover the entire area.

Multi-Strata Flight - refers to a situation where a single aircraft and its crew can survey more than one smaller *stratum* in a single flight session, from take-off to landing

Percentage of Relative Precision (PRP) - is a measure used to indicate the *precision* of an estimated population number. It is calculated as the difference between the population estimate and its 95% confidence limits, expressed as a percentage of the population estimate itself.

Precision - is measure of the consistency and reproducibility of results obtained from a sampling procedure. It quantifies the degree of agreement or closeness between individual data points in a dataset. It is distinct from *accuracy*, which refers to the proximity of the estimate to the true value.

Relative Standard Error (RSE) - is statistical measure that expresses the standard error of a sample or estimate as a percentage of the corresponding mean. It indicates the precision of the data, with a lower RSE value representing higher precision and vice versa.

Sample Survey - is survey in which only a portion of the *survey area* is examined. This specific part is chosen randomly, or without bias. Two common types of sample surveys are *transect surveys* and *block surveys*.

Sampling Units - are the non-overlapping units (i.e. *transects* or *blocks*) used to divide the study area during a sample survey. A random or unbiased subset of these units is selected for an aerial survey, in which the animals are searched for and counted.

Sample Area - is the portion of the *survey area* in a *sample survey* which is searched and counted.

Search Effort - is the average time spent searching per unit area during an aerial survey, usually measured in minutes per square kilometre. See also *search rate*.

Search Rate - average area covered during an aerial survey in a given unit of time, typically measured in square kilometres per minute. See also *search effort.*

Standard Error - is the square root of the population *variance*, serving as a measure of the *precision* of the population estimate.

Stratification – is the division of the *survey area* into subareas called "*strata*" to achieve uniform elephant density within sampling units. This process enhances the precision of estimating the elephant population in the *survey area*.

Stratum (or plural Strata) - is a subdivision of the *survey area* created during the process of stratification. The boundaries of the stratum are drawn to ensure relatively uniform elephant density within the sampling units.

Superstratum (of plural Superstrata) - is a collection of adjacent strata combined into a larger geographical unit for which population estimates are derived.

Survey Area - is the area in which the number of animals is to be estimated. It is equivalent to the study area.

Transect - is a long, straight, and relatively narrow sampling unit, characterised by its parallel placement with other transects within a single *stratum*.

Variance - **Sample Variance** is a measure of the extent of variation in the number of animals counted within each sampling unit, while **Population Variance** is measurement indicating the potential variation in the population estimate if independent population estimates were derived from the observed animal density in each sampling unit.

Zone - in this report it refers to the different larger geographical units for which estimates are derived, i.e., superstratum, country and KAZA TFCA survey area.

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