Community-based Wildlife Monitoring

In Selected Concessions of Chobe and the Okavango Delta, 2013 - 2015

A Partnership between Round River Conservation Studies and the Okavango Research Institute

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Executive Summary

As a United Nations World Heritage Site, designated in 2014, the Okavango Delta region supports the richest biodiversity of southern Africa and its wildlife is highly valued globally, nationally and locally. The Department of Wildlife and National Parks (DWNP) is primarily responsible for wildlife management and conservation in the country and has undertaken significant policy and management steps to ensure the long-term conservation of wildlife throughout Botswana. In 2011, aerial surveys conducted by Elephant Without Borders (EWB) indicated possible widespread declines in several herbivore species across the region (Chase 2011). In 2012, the DWNP and the Southern Africa Regional Environmental Program (SAREP) co-hosted a workshop (DWNP 2012) in Maun that brought together government, academic, regional and local wildlife experts to discuss ways to improve monitoring and management of the natural values of the Okavango region.

Recommendations from this workshop included improving the understanding of wildlife population dynamics and the regulating or driving factors of population trends. Herbivore, carnivore and bird species of concern were some of the targets recommended for increased monitoring, with monitoring approaches detailed in Bourquin and Brooks (2013). Since 2013, Round River has incorporated small groups of advanced university students, community members and local experts to implement the recommended herbivore density and demography surveys (DADS), the bird surveys, and to provide training to escort guides on the field and data management of these surveys. This effort has been a partnership with the Okavango Research Institute (ORI), beginning with Sankuyo, Mababe and Khwai Trusts. Through 2015 this work has included up to 7 concessions in Chobe (CH 1 and CH 2) and the Okavango Delta (NG 18, NG 19, NG 33, NG 34, NG 41). The goals of survey efforts include:

1) Implement statistically robust ways of monitoring wildlife population trends using ground-based approaches as outlined and recommended by Bourquin and Brooks (2013), and

2) Build technical skills and capacity within concessions for survey design, field data collection and management that will allow concessions to eventually assume implement the surveys.

This report summarizes progress towards these goals, focusing on in-depth assessment of the DADS methods, data and analyses options and also presenting the community training efforts and the bird survey development. This report has the following objectives:

1) Summarize wildlife survey efforts undertaken through the partnership of RRCS, concessions and ORI over the last three years;

2) Present the survey data and identify its strengths and weaknesses;

3) Explore robust options for analyzing the data to obtain information on density and demography of selected wildlife species;

4) Based on the above, present recommendations for ways to improve the ground-based wildlife surveys in the Okavango region or meet the goals outlined in the original workshop (DWNP 2012) and in Bourquin and Brooks (2013).

A major component of the work undertaken focused on herbivore surveys using line transect methodology and nicknamed "Density and Demography Surveys" or "DADS". These surveys were designed to complement the ongoing Management Orientated Monitoring Systems (MOMS) monitoring efforts undertaken by concessions. The DADS and bird point count surveys occurred during wet (February-March) and dry (October-November) seasons with field methods outlined in the "Protocol for the monitoring of fauna and flora within Ngamiland, Botswana" (Bourquin and Brooks

2013). Surveys were completed in the dry seasons of 2013, 2015 and the wet seasons of 2014, 2015. The concessions included in each seasonal survey varied, but surveys were completed for all or most seasons for the Okavango concessions ((NG 18, NG 19, NG 33, NG 34, NG 41) and only for 1-2 seasons in 2015 for the Chobe concessions (CH 1, CH 2). Over the four survey periods, more than 4,000km of transects were completed in approximately 436 hours of survey time. There were 37 different species of wildlife recorded with impala, elephant and Burchell's zebra being the most widespread and common.

Exploratory analyses of the herbivore survey data showed that the probability of detecting animals declined rapidly the further the animals are from the transect line regardless of habitat type. Based on the assessment, it is recommended that strip transect-based analyses include animals seen within 50m of the transect line. The use of wider strip widths increased the consequences of violating the analysis assumption of 100% of all animals are counted in the strip and will lead to reduced density estimates.. We estimated density and its standard error and coefficient of variation using a 100m strip width (50m on each side of the transect line) for herbivore species for each concession and season of survey, but only those estimates with CV<0.50 are included in the results.

Line transect analyses using distance methods can account for the decline in detectability with increasing distance from the transect. But these methods can only be used if a sufficient number of observations are obtained to allow modeling of the probability of detection. Given the sample size limitations, we assessed options for pooling data across space and time for selecting a probability of detection function (PDF) that would allow us to use line transect analyses for a broader suite of species. From this assessment, we found that the detectability of some species (i.e., giraffe, impala, kudu) varies by season but for other species (i.e., elephant, zebra) we found data could likely be pooled across seasons for the development of the PDF. For all species, we pooled across the surveyed Ngamiland concessions for PDF development. Based on sample size and our ability to fit an acceptable PDF model, line transect or distance method based density estimates were developed for impala, kudu, elephant, giraffe, steenbok, warthog and zebra for all or some concessions in all or some of the seasonal survey periods.

We also explored the demographic data collected during the surveys including estimating the sex ratios and the juvenile:female ratios. These ratios can provide important ecological information on the health of populations that can complement information on the trends in density or population abundance. We had sufficient demographic information to provide initial ratio information from the seasonal survey efforts for each concession for giraffe, impala, kudu and steenbok.

When available, we present the strip width and distance based results together for comparison. In most cases, the strip width estimate is lower than the distance analysis estimate but wide confidence intervals indicate lack of significant differences between the two. It is expected that strip width densities would underestimate true density even though we attempted to minimize this bias with a very conservative strip width of 50m on each side of the transect. We present only those density estimates with CV $\leq$ 0.50; full results including density analyses with CV > 0.5 are available in the Appendixes.

The density estimates we report from the ground-based transects are notably higher than density estimates from aerial surveys for the same or similar areas (see Chase et al. 2011). We do not have long-term ground-based data to assess population trends, and the higher ground-based estimates do not contradict the suggested trends in wildlife populations revealed in long-term aerial surveys (Chase 2011). There may be multiple reasons for the differences in population estimates drawn from the ground-based and aerial survey approaches.

Our ground-based transect surveys are limited to existing roads and tracks and for many concession areas cover a small percent of the available habitat. In some cases, these roads or tracks may have been developed primarily because high quality local habitat conditions represented excellent wildlife viewing or hunting opportunities for the concessions. As a result, these transects may be primarily in high density areas of each concession and our resulting density estimates reflect this. Alternatively, the aerial surveys have the ability and are designed to sample across the full extent of the concession areas and so include sampling of all habitats available including low density areas so that overall density estimates are lower.

Sightability, either from the ground or air, is a significant issue that must be addressed in developing density estimates. It is not unusual for ground-based densities to be notably higher than aerial surveys, and sightability from the air has been identified as the primary factor underlying the differences (Jachmann 2002). This may be an underlying reason that several authors have noted that aerial census data are prone to underestimate large mammal populations (Bouché et al. 2012, Caro et al. 2000; Stoner et al. 2006). The differences in the estimated densities may be partially due to differences in sightability between the two types of survey approaches.

Despite the differences in density, multiple approaches to monitoring wildlife is desired and recommended (Caro et al 2008) as they provide different resolutions of temporal and spatial scales, unique insights into the dynamics of the wildlife populations and each boasts its own suite of methodological strengths and weaknesses. Careful development, implementation and on-going quality control of the survey effort can lead to effective monitoring of population trends through time. Regardless of the approach to monitoring (e.g., aerial, vehicular, foot surveys), the true value of the data is almost always in the long-term collection of comparable data over several years. Thus, the aerial surveys undertaken since the 1970s in northern Botswana represent an invaluable source of population monitoring if the methodologies are defensible and comparable through years.

The DADS ground-based transects should provide insights into the population dynamics that complement the aerial surveys, and could potentially be used to calibrate aerial census results (Caro, 2012). In time, the on-going MOMS monitoring information should also be incorporated into the on-going management and assessment of wildlife populations in the region, adding additional perspective and information to the management and conservation of wildlife. Such an approach for estimating terrestrial wildlife abundance while integrating local people into scientific and conservation projects may also assist with elevating the vested interest in wildlife conservation by the people who are both influential and affected by these efforts (Ransom, 2012).

Population density estimates, themselves or even coupled with demographic data, provide limited information on the underlying drivers of population trends. Placing population information in the context of landscape and habitat conditions, dynamics and changes would provide the kind of insights needed to make meaningful management decisions now and into the future (Morellet 2007). This is increasingly true as potentially subtle, unforeseen or novel shifts in ecological dynamics arise due to changing climate conditions, expanding human impacts and other emerging threats.

Bird monitoring initially focused on Birds of Concern and expanded to all species in 2015. During the all-species point counts initiated in 2015, 188 different species of birds have been identified with the most common species including Cape turtle dove, Red-billed quelea, Burchell's starling and Red-billed spurfowl. Diversity indexes show that there is higher diversity of birds in riverine or wetland influenced habitats. Bird survey efforts are on-going and developing, and we recommend that the methods be standardized to allow consistent data that are comparable through time to meaningfully contribute to monitoring.

A very important aspect of implementing a standardized wildlife monitoring protocol in communal concessions is capacity building within the local community. Between 2013-2015, a total of 38 community guides from three community trusts participated in the surveys, with 15 and 12 of these returning for a second and third season, respectively. We encourage continued training to reach the long-term goal of transferring the survey effort to the communities. Probably the most important results emerging from the analyses of the data are our ability to assess the utility of the survey effort in providing robust and meaningful monitoring information for herbivores in the region. We provide detailed recommendations to improve these surveys including increasing the survey effort, ensuring the quality of data collected and building collaborative efforts that allow for leveraging individual concession efforts to better understand regional population trends. In summary our most relevant recommendations include:

- Increase the number of concession transects, even if this requires reducing or eliminating repeated surveys of individual transects within a season
- Standardize training and field methods across all organizations and concessions undertaking surveys efforts so data can be combined for analyses
- Establish a Monitoring Working Group that can review the emerging survey efforts and recommendations regarding them, facilitate collaboration and communication amongst organizations undertaking surveys and ensure that methods and training requirements are consistently implemented.
- Increase efforts to put population information into the context of landscape connectivity and habitat conditions, as such an understanding of these dynamics would provide the kind of insights needed to make meaningful management decisions now and into the future.

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Introduction and Background

As a United Nations World Heritage Site, designated in 2014, the Okavango Delta region supports the richest biodiversity of southern Africa and its wildlife is highly valued globally, nationally and locally. The Department of Wildlife and National Parks (DWNP) is primarily responsible for wildlife management and conservation in the country and has undertaken significant policy and management steps to ensure the long-term conservation of wildlife throughout Botswana. In 2011, aerial surveys conducted by Elephant Without Borders (EWB) indicated possible widespread declines in several herbivore species across the region (Chase 2011). In 2012, the DWNP and the Southern Africa Regional Environmental Program (SAREP) co-hosted a workshop (DWNP 2012) in Maun that brought together government, academic, regional and local wildlife experts to discuss ways to improve monitoring and management of the natural values of the Okavango region. Recommendations from this workshop included improving the understanding of wildlife population dynamics and the regulating or driving factors of population trends. Better monitoring of wildlife populations was flagged as an emerging need. These recommendations led to a suite of new wildlife, habitat and environmental monitoring for the Ngamiland concessions that dovetailed with the Management Orientated Monitoring Systems (MOMS) presently in place (Bourquin and Brooks 2013). Herbivore, carnivore and birds of concern were some of the targets for increased monitoring. In response to these recommendations, SAREP developed a ground-based herbivore transect survey approach for implementation in the region to provide demographic and density information at the conservancy level (Bourquin and Brooks 2013)referred to as Density And Demography Surveys or DADS.

Round River Conservation Studies is an international research and education non-government organization that assists governments and communities to develop, implement and meet their wildlife conservation goals. Working with the national government and the local communities of the Kunene Region of Namibia, Round River implemented a community conservancy-level wildlife monitoring and capacity building program (Heinemeyer et al. 2012, 2013, 2014) following similar survey protocols as outlined for the SAREP wildlife monitoring initiative described in Bourquin and Brooks (2013). Since 2013, Round River has assisted Community Development Trusts to implement DADS as well as establish and implement bird monitoring systems. This effort has been a partnership with the Okavango Research Institute (ORI), beginning in Sankuyo, Mababe and Khwai Trusts. Round River incorporates small groups of advanced university students, community members and local experts to contribute to the advancement of the monitoring efforts. The goals of the work include:

1) Implement statistically robust ways of monitoring wildlife population trends using ground-based approaches outlined in DADS, and

2) Build technical skills and capacity within concessions for survey design, field data collection and management that will allow concessions to eventually assume implement the surveys.

This report summarizes progress towards these goals, focusing on in-depth assessement of the DADS methods, data and analyses options and also presenting the community training efforts and the bird survey development. Thus, this report has the following objectives:

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4) Based on the above, present recommendations for ways to improve the ground-based wildlife surveys in the Okavango region or meet the original goals outlined in the original workshop (DWNP 2012) and in Bourquin and Brooks (2013).

This report is structured topically, with a chapter committed to each of the following: herbivore monitoring through bi-annual transect-based DAD surveys, bird and birds of concern monitoring, and community capacity building. Through 2015 this work has included up to 7 concessions in the Ngamiland and Chobe regions (NG 18, NG 19, NG 33, NG 34, NG 41, CH 1 and CH 2). The longest running of these efforts has been in the Ngamiland concessions.

Through 2015 this work has included up to 7 concessions in the Ngamiland and Chobe regions (NG 18, NG 19, NG 33, NG 34, NG 41, CH 1 and CH 2). The longest running of these efforts has been in the Ngamiland concessions. This report provides a summary as well as detailed analyses of the data collected during this period and a suite of recommendations based on these analyses and results to improve the ability of the DADS monitoring to meet the original goals of wildlife and bird monitoring as outlined in the original workshop (DWNP 2012) and in the "Protocol for the monitoring of fauna and flora within Ngamiland, Botswana" (Bourquin and Brooks 2013).

This report is structured topically, with a chapter committed to each of three primary goals of the work: predator and herbivore monitoring through bi-annual transect-based surveys, bird and birds of concern monitoring, and community capacity building.

Chapter 1: Wildlife Density and Demography Surveys (DADS)

The primarily approach to monitoring wildlife in the Okavango Delta region is through fixed-wing aerial surveys. The DWNP conducted 8 standardized aerial wildlife surveys in the region between 1993-2004 (DWNP 1993, DWNP 1994, DWNP 1996, DWNP 1999, DWNP 2001, DWNP 2002, DWNP 2003, DWNP 2004). DWNP then collaborated with Elephants Without Borders, a Botswana non-government research organization in 2010 (Chase 2011) and in 2015 (results not available at the time of writing this report) to conduct aerial surveys.

Reliable estimates of wildlife population trends coupled with insights into the underlying causes for any changes in wildlife population status underpin effective and responsive management and conservation actions. The participants of a 2011 workshop Maun (DNWP 2012) identified the need for additional information on wildlife trends in the form of consistent and more frequent surveys that may capture important population dynamics seasonally or annually, as well as provide insights into underlying drivers of population trends through their composition (e.g., age and sex structure). More broadly, there is an increasing recognition of the significant interest, need and opportunity to develop wildlife monitoring within the communities that share these landscapes with wildlife populations and have a vested interest in the health of the wildlife and the habitats upon which it depends (Msofffe 2010).

Following the Maun workshop, SAREP developed protocols for concession-level wildlife density and demography surveys (DADS) summarized in Bourquin and Brooks (2013). The bi-annual ground-based herbivore surveys are not intended to replace the aerial surveys as the primary data on population trends across this region but focus on providing supplemental information on seasonal abundance and demographic data (sex and age structure) to provide insights into population dynamics. The ground-based surveys are based upon well-established line transect methods and are intended to dovetail with the on-going MOMS (Management Orientated Monitoring Systems) efforts of Okavango regional concessions.

In this chapter, we present the DADS data collected between 2013-2015 by RRCS, communities and ORI and use these data to generate density estimates, provide initial information on demographic characteristics of species with sufficient information. We critically evaluate the ability of the DADS data to provide useful density information including assessing sources of variation, challenges due to sample size and possible opportunities for pooling data to overcome sample size limitations. We present two possible approaches to analyzing the DADS data using strip transect and distance-based line transect analyses for species with sufficient information.

Field Survey Methods

The identification and location of transects largely followed the guidelines in the Protocol for the monitoring of fauna and flora within Ngamiland, Botswana" (Bourquin and Brooks 2013). We strived to use the same transects during each season, but invariably this varied to some degree depending on logistical realities presented by flood patterns and other factors (Figure 1). Surveys were completed during the months of February-March (wet season) and October-November (dry season).

Field surveys were conducted following a number of driving speed and observer numbers. Routes were surveyed in the morning, beginning no earlier than half an hour before sunrise and ending no later than 1130 hours' even if the route was not completed. This survey window maximized efforts during the highest visibility times and avoided times when animals are more likely to have bedded down to avoid the heat. Each survey route was recorded using a GPS unit. Information including survey route information, observers and weather conditions was recorded at the start of the survey (Appendix I). As per Bourquin and Brooks (2013) protocols, transects were surveyed three times each season, with two days in between each repetition.

We attempted to have each survey staffed by 4 people, typically a community escort guide, a Round River biologist, and 2 or more students. The team consisted of a driver, a guide with knowledge to ensure the survey followed the designated route, and 2 observers in the back. Within season variation in this was unavoidable and there were occasions each season in which the team consisted of 3 (14% of the time) or 5-6 people (14% of the time) depending upon escort guide and student availability and training opportunities. In the 2014 wet season, 26% of the surveys were conducted with3 people, two Round River staff and 1 student intern due to lack of available staff. All team members were trained in the survey design and protocols and were proficient in the data collection methods. All team members searched for wildlife without the aid of binoculars, with the front passenger primarily responsible for searching for animals ahead along the transect line, while the two members in the back of the vehicle searched the areas on each side of the road. The driver did not exceed 10 km/hour. When animals were spotted, the vehicle was stopped and data obtained to calculate the location of the animal(s). A GPS location within a 5m accuracy was recorded at the vehicle, and radial distance data were collected (Buckland et al. 2011): the distance to the wildlife and the compass bearing.

The radial distance between the vehicle and the center of the group of animals was estimated using a laser range finder (Nikon Laser 1200 Monarch Gold and Leupold RX 1000i) and compass angle. The distance was recorded where the animal group was originally spotted (not to where it may have travelled since observation). If the initial sighting is of animals already fleeing this was noted and the observation removed from the data prior to analyses. To increase the successful use of the range finder, the vehicle was turned off at each animal sighting. If the animal exceeded the distance possible for the range finder, the reading on the range finder appeared inaccurate or the range finder was otherwise not functioning, the the senior team members made a visual distance estimate and it was noted that the distance was visually estimated on the data sheet. The observers all practiced visual distance estimation to minimize errors in data collected without the aid of a laser range finder. Using a compass, the angle (from true north) to the animal (s) was recorded to the closest degree. The species and group size were recorded, as well as the sex and age class (adult, subadult, young of year) of all individual animals, if possible on standardized data sheets (Appendix I). Habitat type at sightings was also recorded, using 14 individual habitat codes (Appendix I). Other comments were noted such as "fleeing," and "in village."

Defining whether a species is to be counted in groups or individually is an important decision and affects the structure of the data and resulting assumptions during analyses. The decision should be based upon social structure and seasonal ecology of each species. We defined all species we expected to encounter along the routes as occurring in groups (which could be composed of a single individual in some cases). A group of animals was defined as individuals of the same species that appears to visually constitute a unit or cluster. When a group of animals was sighted, a central point was established within the group in order to measure a distance and angle from the vehichle. Data were collected for all encountered wild large mammals (the smallest being steenbok (*Raphicerus campestris*)), as well as for ostrich (*Struthio camelus*) and crocodile (*Crocodylus niloticus*).

When possible, measurement accuracy was increased by moving the vehicle along the transect closer to the spotted animal(s) to collect the survey data. The location of the animal(s) was later calculated based on the location of the vehicle, the distance and compass bearing of the animal(s) from the vehicle. The distance of the animal(s) to the nearest point along the transect (i.e., the 'perpendicular distance) was estimated based on the calculated location of the animal(s). While other studies have estimated perpendicular distance of the animal(s) to the transect in the field (e.g., K. Golabek, pers. comm), we used the radial distance approach recommended in Buckland et al. (2011) to avoid issues such as flushing the animal(s), losing animals and observer error in estimating the transect location closest to the animal (challenging if transects are not straight, are in rolling terrain or winding through thicker vegetation.

The protocols do not allow observers to use binoculars to search for animalsbut binoculars were used to collect count, age and sex data on the spotted animal(s). If this led to increased counts for that group or new observations of other species or other groups of the same species, data were collected on these additional animals and the use of binoculars was noted within the comments section of the data sheet. Binoculars were not used from a moving vehicle and the vehicle was not stopped only to scan the landscape with binoculars nor did the vehicle remain stopped for scanning beyond the time needed to record initial sightings.

Observers remained as quiet as possible while surveying to avoid alerting animals to their presence. If another vehicle was encountered along the route, the research vehicle was stopped and remained so until the encountered vehicle had passed and was no longer in the field of view. At the completion of the survey, the information including the time end, odometer end, and end GPS waypoint were recorded (Appendix I). We attempt to repeat the same transects during each survey season, but conditions (e.g., flooding, downed trees, etc) make force small deviations along the route. Each season, a GPS track was collected for each transect to ensure the correct route was used in the calculations of perpendicular distance.

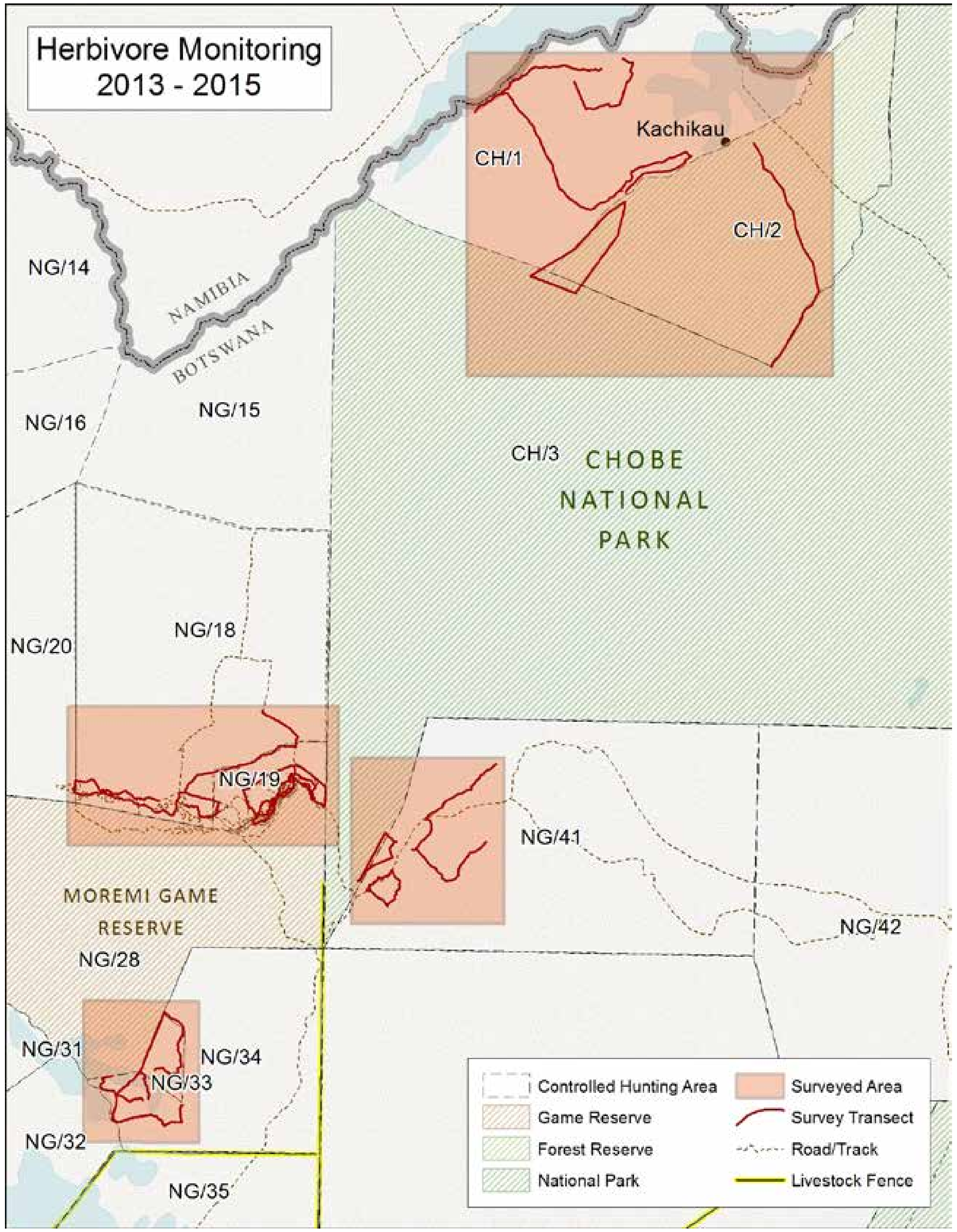

Figure 1. Study area map showing transect routes followed for wildlife Density and Demography Surveys (DADS) in selected concessions of northern Botswana.

Analyses Considerations and Methods

There are two primary approaches to transect abundance estimates: strip transect and line transect (also referred to as distance analyses). Each method has a suite of assumptions that must be understood to appropriately implement, analyze and interpret the data and the results. Both assume that the transect is placed to allow random sampling of the distribution of the species of interest – i.e., transects should be placed randomly or systematically relative to species distribution and density within the study area or sampling area. The use of existing roads as transects violates this major assumption but the realities of conducting surveys of sufficient length and effort have resulted in the relatively common use of roads for transect surveys despite the known assumption violation. It is also assumed that the transect itself does not influence the species distribution (e.g., animals do not avoid being near the transect route).

The strip transect approach defines an area (strip) on either side of the transect which is searched for the species of interest. Individuals within the strip are counted; animals outside the strip can be ignored (Buckland et al. 2011). Strip transect analyses make the critical and invariably violated assumption that 100% of the animals within the strip are counted and density is most basically derived by animals counted/strip area. The undercounting of animals due to sightability limitations is not accounted for in strip transect approaches and leads to the under-estimation of density (Oguto et al. 2006, Azhar et al. 2008, Shorrocks et al. 2008, Buckland et al. 2011).

In line transect or distance-based surveys, all animals are recorded regardless of the distance between the animals and the transect. This approach recognizes that the probability of detecting an individual or group of animals declines with increasing distance from the transect but, importantly, assumes 100% or nearly 100% of animals are counted at the transect line and that animals are distributed randomly and uniformly with respect to that line (Buckland et al. 2011). It uses the distribution of counts by distance from the transect to fit a model of the probability of detection given distance from the transect (Buckland et al. 2011). Critical and often violated assumptions in addition to the ones described above include exacting field techniques needed to obtain accurate estimates of the distance from the transect for observed animals. The benefits of the line transect approach include explicitly accounting for sightability and being able to include all or most animals observed in the data analyses (though those closer to the transect are most important).

Information about the age and sex composition of a population can provide insights into the underlying population dynamics contributing to long-term population trends and health of a population. Wildlife managers have long used demographic data to look at annual mortality and survivorship rates, sex ratios, and age class ratios as indexes of population health (Bender 2006). Demographic data can provide insights into population trends while requiring less effort than other costly methods of population management (Bender 2006). Selected demographic analyses have fewer requirements and assumptions, allowing managers to collect and analyze the data relatively easily and with little potential for calculation error. Using the herbivore data collected from 2013-2015, we looked at the gender and age ratios of impala, kudu, giraffe, and steenbok and suggest recommendations for future demographic data collection.

We undertook a careful evaluation of the survey data to explore options for population density and trend monitoring including demographic monitoring and density monitoring using strip transect and line transect approaches.

Line Transect Methods

Line transect or distance-based density estimation requires the following assumptions be met in regards to the field data collected (Buckland et al. 2011, Krebs 2014):

1) Animals directly on the transect line will never be missed (i.e. their detection probability = 1);

2) Animals are fixed at the initial sighting position; they do not move before being detected and none are counted twice;

3) Distances and angles are measured exactly with no measurement error and no rounding errors;

4) Sightings of individual animals or groups of animals are independent events.

These are in addition to the assumption of uniformity which, as discussed above, assumes that the animals being sampled are distributed randomly with respect to the transect.

Data were collected using protocols appropriate for distance-based analyses. We evaluated our ability to use distance sampling models to estimate seasonal concession-level population densities for herbivore species using data collected over the 4 seasonal survey efforts between September 2013 – November 2015. We used the Distance Program 6.0 (Thomas et al. 2010) including both conventional and multi-covariate distance sampling engines to evaluate and analyze data.

Sample size and data pooling considerations. In broad terms, there are three important inputs that drive the estimates of density: the probability of detection or seeing an animal(s) given it is there (modeled as a 'probability of detection function or PDF); the encounter rate (i.e., how many times a species is seen per kilometer of transect) and group size (how many individual animals there are in each observation). Note that two of these important metrics are focused not on the total number of animals seen but on the number of times the species is seen along the transect. Thus, distance analysis is challenging or impossible for species that occur in large herds which are spotted only a few times within a survey area.

In general, small numbers of observations of most species severely limit our ability to use distance analyses, particularly because the development of the probability of detection function (PDF) requires large sample sizes relative to typical number of observations in a concession survey. It is important to identify where we can justify pooling data to effectively increase the number of observations and generate robust probability of detection functions.

We used the data on impala, and where sample sizes were sufficient on elephant, giraffe, kudu and zebra to evaluate the influence of sample size, concession, season and local vegetation on the detection probability to determine if and where pooling of data may be possible for developing the PDF for line transect analyses.

Repeated transect data. The survey protocol (Bourquin and Brooks 2013) includes repeating the survey effort 3 times along each established transect in each season (with a minimum of 2 days apart). These repeats are not independent of each other and the data needs to be appropriately handled in the analyses. We assessed multiple ways of including the replicate data including analyzing each replicate separately, pooling replicate data for the development of the PDF but generating densities independently for each concession-level replicate, and pooling the data to generate a single density estimate for survey effort. Pooling repeated survey data by transect to develop the density estimate is the recommended approach for dealing with repeated survey data (Buckland et al. 2011) and avoids incorrectly inflating your apparent number of samples (i.e., transects). Density estimates are the same whether the repeats are analyzed individually and repeat densities averaged or repeats are pooled by transect, but the two approaches have very different variance estimates. The former estimates only the variance between the estimated densities while the latter more appropriately estimates the variance between samples (transects). Buckland et al. (2011) recommends the latter approach in which each transect is entered as the pooled transect data and total effort (km surveyed). Thus, if a transect is 10km and it was surveyed three times, the effort would be 30km and the animals included in the analyses would be combined over the 3 surveys.

Distance model development. When sample size and other key assumptions were met, we proceeded to model selection and the development of distance-based density estimates for each concession and season surveyed. Details of this process are in Appendix III. We accepted the estimates when the probability of detection model fit the data sufficiently (chi-square value ≤ 0.8) and the co-efficient of variation for the density estimates was < 0.50.

Strip Transect Methods

We identified a 100m strip width (50m each side of transect) to be used for calculating the strip transect density estimates. This decision was based on the shape of the animal count distribution when plotted by distance from the transect. The selected width attempted to balance the known reduction in detectability with increasing distance with including sufficient width to enable reasonable density estimates. The strip width selected has a major influence on the resulting density estimated due to the assumption that 100% of animals are seen within the indicated strip combined with the known violation of that assumption based on declining detectability, which becomes more extreme the wider the strip.

We calculated the total individuals counted for each species within the strip width based on the calculated location of the center animal of groups, which is how the data were collected as per line transect protocols. This may result in some inaccuracy in using strip transect analyses as only those individuals of the group that were within the strip width should be included and any individuals outside the strip would be excluded. We assume this is balanced by excluding all groups whose central animal and thus group location fell outside the strip width though it would be equally likely that some of the individuals of those groups were inside the strip.

We could not find recommendations for incorporating repeated surveys (3 surveys completed each season, at least 2 days apart) into the strip transect analyses. We evaluated 2 approaches to handling the repeated surveys but have concerns about both. One approach estimates a density for each repeated set of surveys in a concession and produces a weighted average of these 3 estimates for the concession for each season (e.g., 2015 wet season) with weighting based on total transect length of each repeat. The variance in this case is represents the variance of density estimates themselves, not the underlying variation across the sampling units (i.e., the transects). The appropriate metric of variance should consider the transect as the sample unit, so we also evaluated generating a density estimate using individual transect surveys as the sample unit. In this case, each repeat survey of the transect is considered independent. The estimated density is the same as above. The variance in this approach captures the variance between different transects within a concession as well as the temporal variance represented by each transect . Similar to the first approach, this one erroneously treats each repeat as independent but may be a better representation of the true variation because it captures the variation between different transect routes (i.e., the spatial variation across the conservancy) which is lost in the first approach. A third option may be to pool repeats by transect, as is recommended by Buckland et al. (2011) for line transect analyses, and may be explored in the future. Calculations were based on Krebs (2013), where the weighted density is:

$$\widehat{D} = \frac{\sum_{i=1}^{R} l_i D_i}{\sum_{i=1}^{R} l_i}$$

And the variance is:

$$\text{var}(\widehat{D}) = \frac{\sum_{i=1}^{R} l_i \, (\widehat{D_i} - \widehat{D})^2}{\sum_{i=1}^{R} l_i (R-1)}$$

In these equations, the definition of l_i and R varies depending upon the definition of the sample unit that is the basis of the calculation. In the first approach, the sample unit is each survey, making l_i the total transect length of each survey i and R equal to the number of survey replicates (typically 3 in this case). In the latter approach, l_i is the transect length of each individual transect i and R is the total number of transects surveyed including each repeated transect survey (e.g., most concessions have 4 transects that are surveyed 3 times each season making R = 12 in most cases).

The standard error of the mean (SE) and the coefficient of variation of the density estimates for either estimate are calculated as:

$$\text{SE}(\widehat{D}) = \sqrt{\text{var}(\widehat{D})}$$

and

$$\text{CV}(\widehat{D}) = \frac{\text{SE}(\widehat{D})}{\widehat{D}}$$

Typically, the CV is calculated using the standard deviation. When estimating the variance as the variance in sample means (rather than from individual observations), the SE is the standard deviation of the sample mean (Everitt and Skrondal 2010), and so we used the SE to calculate the CV.

Densities were calculated for each concession, each season and each herbivore species with sufficient information. These species include elephant, giraffe, impala, kudu, steenbok, warthog and zebra. We explored opportunities to develop density estimates for other herbivore species were data allowed.

Demographic Analyses Methods

Wildlife is most commonly classified into age classes (e.g., juvenile, sub-adult, adult) which is much more feasible to collect in the field than the actual age of the animal. The definition of age class stages is dependent on the life history of the species and characteristics that can be consistently identified in the field without requiring more invasive techniques (Akcakaya 2000). Population models that estimate the trend of the population based on the sex and age structure data are powerful, but they also have high information requirements including estimates of survival rates by sex and age class and reproductive rates. Fortunately, it is possible to glean insights into these important population drivers by looking at the ratios between sex and age classes. These ratios can be readily calculated from field data though there must be enough individuals in each stage so that ratios can be calculated with reasonable accuracy.

The sex ratios in natural populations are not necessarily 1:1 for all species, generally due to the slightly higher mortality in males (Owen-Smith & Mason 2005) and potentially skewed sex ratio at birth. Sex ratios can provide insights into the population health when combined with age ratios and density across seasons and concessions. Looking and analyzing the demographic data now will also allow us to assess the future potential of creating Leslie matrix models to examine population trends based on demographic characteristics.

It is important to interpret age and sex ratios in light of other population information, as these ratios cannot explain population dynamics by itself (Conservation of Wildlife Populations 2013). While higher age ratios (e.g., high calf:adult female ratio) usually indicate a healthier population, there are multiple factors that may influence these population demographics. This includes biases towards detectability across sex and age classes (Bonenfant et al 2005) and that population change is not solely influenced by annual reproduction (Bender 2006; Conservation of Wildlife Populations 2013).

One of the primary goals of the DADS effort is to obtain demographic data that can enhance the interpretation of density and density trends (DWNP 2012, Bourquin and Brooks 2013). We undertook preliminary analyses of demographic data to assess the utility of current data collection efforts, explore the potential of creating population models based on demographic characteristics and to provide recommendations to improve the effort to collect these data. Sex ratios were used for either adult or adult and sub-adult individuals within a population, depending on what was most appropriate for the specific species and what was recommended in the literature. Age ratios were created by looking at the number of juveniles compared to adult females.

Table 1. Summary of herbivore survey effort across identified concessions in northern Botswana including the average survey distance per survey replicate and the range of distances across the 3 replicates completed each season, and the number of transects within each concession.

Concession	Dry 2013 Survey Distance (range) - # of Transects	Wet 2014 Survey Distance (km) - # of Transects	Wet 2015 Survey Distance (km) - # of Transects	Dry 2015 Survey Distance (km) - # of Transects
NG18	51.55 (38.22-62.82) - 3	37.75 (37.27 - 38.22) - 2	75.7 (74.5 - 76.3) - 4	89.52 (83.85 - 92.41) - 4
NG19	61.99 (44.91 - 73.35) - 4	38.44 (37.46 - 39.03) - 2	78.13 (77.2 - 78.9) - 4	79.51 (74.51 - 82.9) - 4
NG33/34	81.04 (78.03 - 83.18) - 4	49.47 (48.5 - 50.73) - 2	79.93 (78.8 - 81.9) - 4	77.82 (76.94 - 78.76) - 4
NG41	87.95 (77.74 - 106.47) - 4	39.71 (38.73 - 41.02) - 2	84.5 (80.5 - 88.7) - 4	81.28 (78.41 - 85.47) - 4
CH1	N/A	N/A	61.9 (59.5 - 63.2) - 2	102.19 (96.9 - 105.11) - 4
CH2	N/A	N/A	79.03 (76 - 81.1) - 2	N/A

Herbivore Survey Results

Summary of Effort

Surveys were undertaken four times between September 2013 and November 2015 for concession areas Sankuyo (NG33/NG34), Mababe (NG41) and Khwai (NG18/NG19): Sept/Nov (dry season) 2013, Mar/Apr 2014 (wet season), Mar/Apr 2015 (wet season) and Sept/Nov 2015 (dry season). In addition, surveys were completed in concession area CH1 for the 2015 wet and dry season and CH2 for the 2015 wet season. Transects were surveyed at least three times each season the surveys were undertaken in each concession area with at least 2 days between replicate surveys. The same transect routes were driven during each survey replicate (Figure 1, Appendix I) though there was some variation in routes and total kilometers driven due to logistical issues and changing road conditions (Table 1).

An average of 1003.06 km of routes were surveyed per season over an average 111.29 hours of observation time. Of these, an average of 659 km represents survey effort to complete replicates 2 and 3 per season and per protocol. Over the four seasons, a total of 4,012 km of routes were surveyed over 436.3 hours of observation time. Of these, 2,636 km represents survey effort to complete replicates 2 and 3 per season as per protocol. Most seasons the full suite of 4 transects identified within each concession were surveyed three times; in the wet season of 2014, only two transects were completed and each of these 2 transects were repeated 3 times. The average transect route length was 21.6 km but was variable (range: 9.8 – 41.3 km) and took an average of 2.4 hours to complete (range 1.0 – 5.2 hrs). As per protocol, surveys started in the morning (average start time 6:40) and ended before 11:30 (average end time 9:01) to minimize the biases in survey data that would be introduced by potential effects of hot weather on wildlife behavior and sightability.

Summary of Data

Thirty-six wildlife species were recorded during the herbivore surveys (Table 2). Common species across most concessions included impala, elephant, and Burchell's zebra. These species were relatively common across most concessions and abundant in some concessions. Other species that were widely distributed but lower in numbers in most concessions included giraffe, warthog, and kudu. Several species were found in lower numbers but some of these were more abundant locally in some concessions (e.g., African buffalo and wildebeest in Mababe). Noteworthy rare sightings included 3 sable in Khwai in Sept/Nov 2013, 4 cheetah in NG34 in Sept/Nov 2013, 2 bat-eared foxes in Khwai Sept/Nov 2015 and 3 eland in NG41 in Sept/Nov 2015.

Number of groups or individuals seen and fluctuation in average size of groups are considerations when calculating density of wildlife. Therefore, we summarize the number of groups and average size of groups across replicates, across concessions and across years

Table 2. Species recorded during herbivore monitoring counts in 6 concessions in the eastern part of the Okavango Delta, Botswana from October 2013 through December 2015.

Species	Latin Name	CH1 n=18	CH2 n=6	NG18 n=38	NG19 n=39	NG33/34 n=42	NG41 n=42	Grand Total
African buffalo	*Syncerus caffer*	148		36	52	186	2392	2814
Baboon	*Papio ursinus*	7		98	96	71	139	411
Banded mongoose	*Mungos mungo*			4	22		27	53
Bat-eared fox	*Otocyon megalotis*			1			2	3
Black-backed jackal	*Canis mesomelas*				1	8	11	20
Cheetah	*Acinoyx jubatas*					4		4
Crocodile	*Crocodylus niloticus*				6	3	5	14
Duiker	*Sylvicapra grimmia*	5	5	1		1	4	16
Dwarf mongoose	*Helogale parvula*			2	3	8		13
Eland	*Taurotragus oryx*	37					14	51
Elephant	*Loxodonta africana*	123	5	245	254	469	539	1635
Giraffe	*Giraffa camelpardalis*	71		189	91	281	169	801
Hippo	*Hippopotamus amphibius*			86	410	50	174	720
Honey badger	*Mellivora capensis*				1	1	2	4
Impala	*Aepyceros melampus*	175	17	1772	3241	3334	2119	10658
Kudu	*Tragelaphus strepsicerus*	34	2	167	171	172	66	612
Large grey mongoose	*Herpestes ichneumon*	1						1
Leopard	*Panthera pardus*			1	7	2		10
Lion	*Panthera leo*			2	15	3	11	31
Ostrich	*Struthio camelus*	27		13	12	14	48	114
Red lechwe	*Kobus leche*			138	132	206		476
Reedbuck	*Redunca arundinum*			45	17	6	14	82
Roan	*Hippotragus equinus*	1		25	2	3	27	58
Rock python	*Python sebae*					1		1
Sable	*Hippotragus niger*			1	3			4
Side-striped jackal	*Canis adustus*	1						1
Slender mongoose	*Galerella sanguinea*						3	3
Spotted hyena	*Crocuta crocuta*	2			18	5	3	28
Steenbok	*Raphicerus campestris*	5	6	18	19	62	64	174
Tsessebe	*Damaliscus lunatus*			30	25	48	89	192
Vervet monkey	*Chlorocebus pygerythrus*			50	4	14	10	78
Warthog	*Phacochoerus africanus*	40	4	53	123	78	141	439
Waterbuck	*Kobus ellipsiprymnus*			114	202		77	393
Wild dog	*Lycaon pictus*		3		23			26
Wildebeest	*Connochaetes taurinus*	18		3	54	15	530	620
Zebra	*Equus quagga*	1049	4	126	407	188	700	2474

for the most abundant species: African buffalo, elephant, giraffe, impala, kudu, steenbok, wildebeest and zebra. This is available in Appendix II.

Data collection on wild dogs, lion, leopard, spotted hyena and cheetah is also of interest and the SAREP protocols includes a focus on these species (Bourquin and Brooks 2013). Across the four seasons, 26 wild dog, 10 leopards, 31 lions, 4 cheetah and 28 spotted hyena observations were recorded. The total number of actual individuals is unknown. In order to eventually be able to identify individuals within and across seasons, photographs were attempted to assist SAREP's online predator ID database. Round River will continue collecting information on these species to contribute to this ID database and advance the understanding of predator populations in the concessions where we work.

Distance to Transect Distributions

Whether line or strip transect approaches are used to estimate density, it is important to understand the spatial distribution of the animal data relative to the transects. In general, it is expected that the highest percent of animals are seen closer to the transect line and decline with increasing distance. The distance at which a notably lower percentage of animals are seen is an important metric that affects both transect analyses.

Strip transect analyses assumes that 100% of the animals are seen within a defined distance from the transect (i.e., the strip width) and ignores animals seen beyond this point. Therefore, it is critical to select the strip width based on the expected sightability of all animals. Defining a strip width wider than is reasonable to have sighted most or all animals results in an estimated density lower than the true density. Pooling all of our count data shows the typical decline in total counts with increasing distance intervals (Figure 2). In Figure 2, we also show the percent of the animals that were actually seen if we assume nearly 100% of the animals are seen within 25m of the transect and if the underlying distribution of animals was relatively uniform across the distance strata.

Line transect analyses assume that nearly 100% of animals are seen at zero distance from the transect (Buckland et al. 2011) and models the decline in the probability of detecting animals (Figure 3), allowing an estimate of density that uses all or most of the count data collected across all distances. This has strong advantage over strip transect analyses if assumptions can be met.

The distribution of many species we recorded show the classic declining counts with increasing distance from the transect (Appendix II). For most species, there is a significant drop in the estimated percent of animals seen at distances greater than 50m from the transect line. We chose 50m from the transect line to define our strip transect width for all species, reducing the bias of sightability that is expected to underestimate densities. Species with few data did not always exhibit the classic declining sightability with distance distribution possibly due to insufficient sample size; calculating density for these species is challenging. Additionally, hippo would not be expected to have high counts at the transect (i.e., at zero distance) given transects were road-based and they are primarily seen in adjacent waterways.

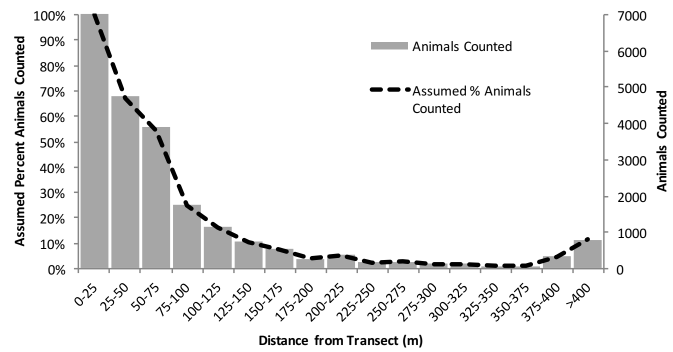

Figure 2. Distribution of count by distance from the transect line, assuming that 100% of animals are counted between 0-25m.

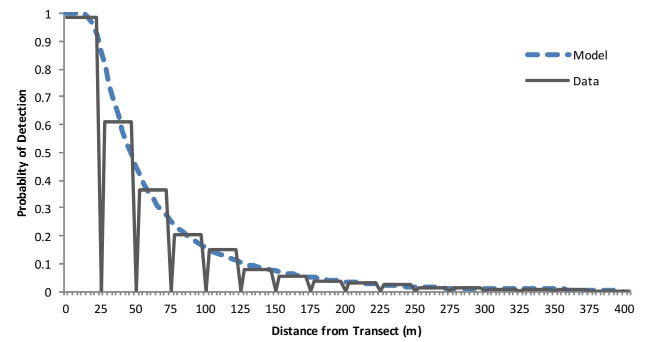

Figure 3. A probability of detection model fitted to the count data of all animals indicating that the probability of detection declines with distance from the transect, similar to the distribution shown in the previous figure.

Distance Analysis: Sample Size Limits and Data Pooling Evaluations

Sample Size Influence on PDF and Density Estimates. We determined that reasonable approximation of a PDF and estimated density requires a sample size of at least 250-300 observations (Appendix III) though this is likely dependent upon the underlying distribution of the count data relative to the distance from the transect. We used this as an approximate guide to identifying those species with sufficient data for distance analyses while still evaluating species with >90 observations pooled across the suite of appropriate concessions and seasons. This is higher than the 60-80 minimum observations suggested in Buckland et al. (2011).

Standard errors are relatively high even with our larger sample sizes, resulting in large confidence intervals surrounding any estimate (Appendix III). Showing a statistically significant change in population density would be extremely challenging given the sample sizes and resulting standard errors we obtain over all species. Still, generating densities themselves can provide insights into population trends if caution is used in the interpretation of possible changes in the estimates through time and space.

Seasonal Effects on Probability of Detection. We assessed the variability in the PDF between the dry season surveys and the wet season surveys. We pooled each species survey data across concessions and years for this assessment to estimate a PDF for each season. Season has a variable effect on the PDF model depending on the species (Figure 4). For most species, the best fitting models suggest that probability of detection at distances from approximately 25m to 200m is higher in the dry season. For example, the probability of detection for impala is predicted to be 50% at 50m during the dry season, dropping to 30% in the wet season. To examine the difference between the PDF curves, we calculated the difference between them at each distance and display this difference in the lower right panel of Figure 4. Arbitrarily, we have indicated a difference of 10% in predicted detectability between seasons on the figure with the indicated bar and have identified species with <10% maximum difference to pooled across seasons to calculate a single PDF model while species with >10% maximum difference require separate PDF models for wet and dry seasons.

Both elephants and zebra show maximum differences less than 10% between seasonal probability of detections (Figure 4, lower right panel). For example, the most pronounced difference in the seasonal zebra PDF is only 6%, and is only 8% for elephants. This suggests that we may be justified in pooling data across seasons for the generation of a global PDF for zebra and for elephant, while other species including kudu, impala and giraffe likely require that the PDF be generated separately for each season. This is important, as the ability to pool across seasons can substantially increase our sample size to generate a PDF model. It is interesting that giraffe have higher detectability in wet season than the dry season, as most other species with seasonal differences show the opposite. Apriori, it may be expected that detectability is higher in the dry season when many plant species are dormant and without leaves.

Local Habitat Effects on Probability of Detection. We found that local habitat structure influences the probability of detection using impala as the primary test species with adequate sample size (Appendix III). This is slightly more pronounced during the wet season, when foliage would be out creating an enhanced visual barrier (Figure 5). We also evaluated the influence of local habitat on the PDF of zebra and found it had less influence on the detectability of this species. Data were inadequate to evaluate other species including elephant, giraffe and kudu as most locations were classified as closed habitat (for habitat classification definitions, see Table A-5 in Appendix III). Ideally, habitat structure would be included as a co-variate in the distance analyses but exploration of this option indicated that we do not have sufficient sample size to include covariates in the distance modeling, even when simplifying to a 2-class variable. We found the influence of local habitat structure had less than a 10% maximum effect on the absolute probability of detection and therefore likely has minimal influence on analyses, unlike season which has a large influence on the PDF for some species (Appendix III).

Probability of Detection by Concession. Concession-level sample sizes were insufficient to compare PDF models across concessions and we were unable to use analyses to guide appropriate pooling. We have assumed that the habitats and populations within Ngamiland are similar enough to warrant pooling for the development of the PDF models. We assume that the Chobe concession habitats and population distributions may be different in important ways from the Ngamiland areas and therefore Chobe concession data were not further analyzed under a distance framework given insufficient sample sizes.

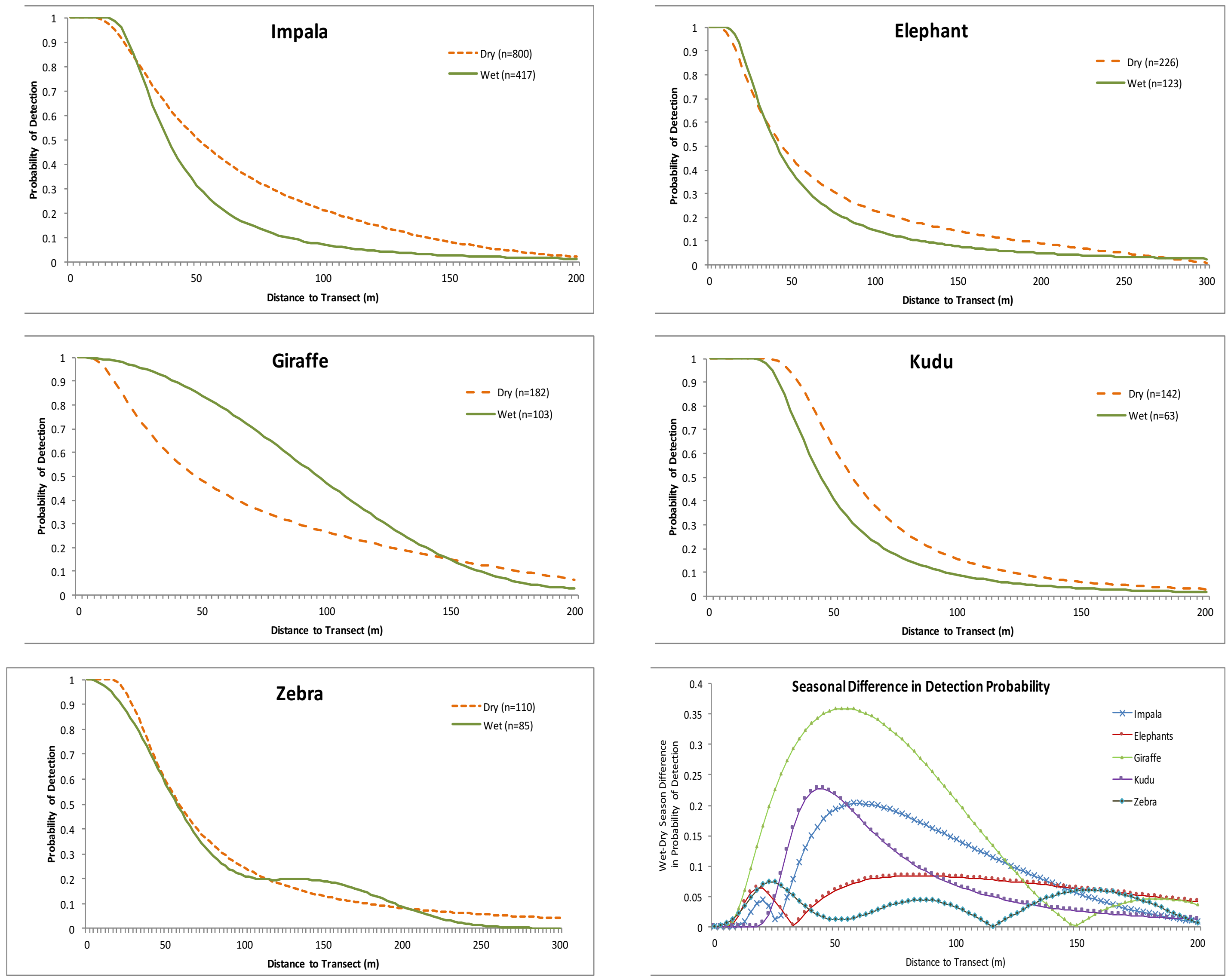

Figure 4. Seasonal variability in the probability of detection function model for impala, kudu, elephant, zebra and giraffe with the lower right panel showing the absolute difference between wet and dry season for each species.

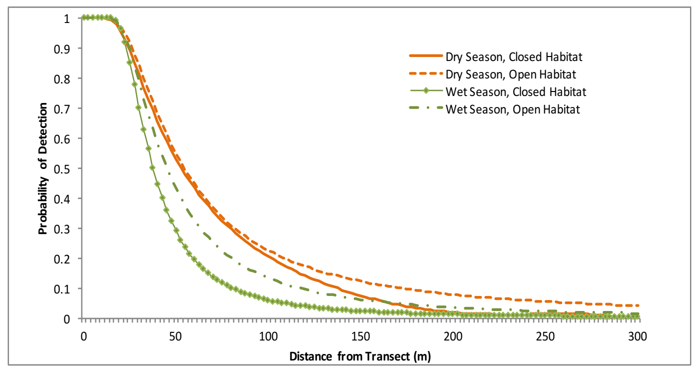

Figure 5. Probability of detection of impala generated from subsampling data for season and local habitat.

Table 3. Probability of detection function (PDF) model selection and results of Ngamiland concessions including the number of transects, total number of groups, selected model based on AICc, its chi-p value and the effective strip width (ESW) for species and seasons.

Species	Season	# Transects	# Groups	Model/Function	Chi-p	ESW
Impala	Dry	30	773	Hazard/Polynomial	0.94	67.7
Impala	Wet	23	403	Hazard/Polynomial	0.83	48.3
Kudu	Dry	30	128	Hazard/Polynomial	0.87	70.7
Elephant	All Seasons	53	304	Hazard/Polynomial	0.80	67.7
Giraffe	Dry	30	162	Hazard/Polynomial	0.88	71.2
Giraffe	Wet	23	96	Half-normal/Cosine	0.79	99.1
Steenbok	Dry	30	112	Neg Exp/Polynomial	0.80	32.2
Warthog	Dry	30	113	Half-normal/Cosine	0.888	63.7
Zebra	All Seasons	53	133	Hazard/Polynomial	0.83	81.7

Distance Modeling

We examined our ability to develop appropriate distance-based detectability models for Ngamiland concessions using detection rates pooled for the development of the PDF. We attempted to fit models for species with >90 observations within a season that appeared appropriated distributed (e.g., declining relatively smoothly with distance). These species included elephant, giraffe, impala, kudu, steenbok, warthog and zebra. We pooled across wet and dry season survey data to evaluate PDF models for elephant and zebra but separated wet and dry season data for the other species. The three replicates collected for each transect within a season were pooled including the cumulative distance surveyed and all encounter data (Table 3). Pooling data across Ngamiland concessions dramatically increased key sample numbers including the number of transects which is used to determine variability in encounter rate and the number of groups which determines selection and fit of the PDF model (Table 3). In all cases, we binned data by distance intervals to increase model fit (Figure 6), and were able to achieve a minimum chi-p $\geq$ 0.79 for impala and giraffe in wet and dry season models, elephant and zebra in combined seasonal data, and dry season models only for kudu, steenbok and warthog.

We did not pool data for encounter rate (# observations/km of transect) and group size, and these were determined from concession-level seasonal data to provide for concession and season-specific density estimates (e.g., impala in NG 19 in 2015 wet season). Regression of group size by distance from the transect was completed for each survey period and if the regression was significant at p<0.15, the modelled group size was used; otherwise the average group size was used. Modeling parameter estimates and results are summarized in Appendix III, while density results themselves are summarized by species in the following sections.

Density results are provided only for concession estimates with a density estimate CV<0.5. Our ability to estimate acceptable densities varied by species, season, and concession and is not necessarily due to sample size limits but also due to the variability in detection probability, encounter rates and group sizes.

Strip Transect Analyses

A fundamental assumption of strip width-based density estimation (strip transect analyses) is that all animals present within the strip width are identified and counted. Typically, the width of the strip is established prior to field data collections and only animals falling within the defined strip width around the transect are counted. We collected information for all animals detected, following protocols for distance-based sampling and calculated the perpendicular distance to the transect from this data for all animal groups. Thus, we had the opportunity to test a diversity of strip width definitions against the critical assumption of counting all animal in the defined strip and maintaining a transect strip wide enough to meaningfully estimate densities. Based on the distribution of counts relative to their distance from the transect, we chose a strip width of 50m on each side of the transect. Thus we have assumed we counted all animals within the 100m strip bounding each of the transects (see Methods for additional details).

As described in the methods, we evaluated 2 options for handling the repeated survey design in the density analyses; both options suffer from assuming independence of repeated surveys. The first option calculates variance based on the difference in the densities calculated from each of the three repeats completed for each survey. This approach does not consider the

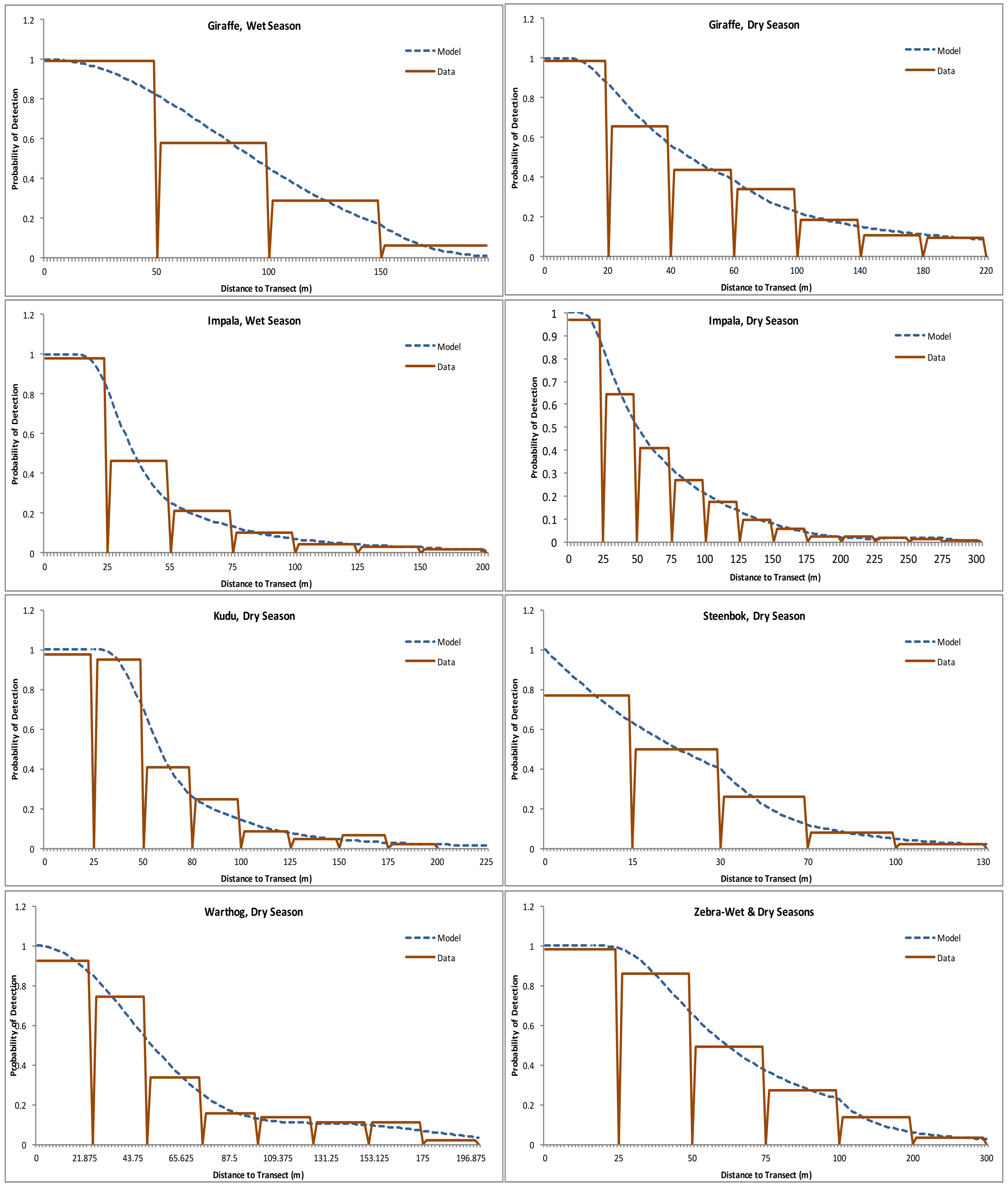

Figure 6. Fitted model with animal data for each species data pooled either by wet or dry season or across both seasons.

Table 4. Comparison of two approaches to calculation standard error: 1) based on variation between replicate densities which capture temporal variation only (SE_T) and 2) based on variation across transects and their replicates which captures both temporal and spatial variation (SE_F); also shown is the percent of the full SE represented by the temporal component.

Species	CH 1			NG 18			NG 19			NG 33/34			NG 41			Ave %
	SE_T	SE_F	%	SE_T	SE_F	%	SE_T	SE_F	%	SE_T	SE_F	%	SE_T	SE_F	%	
Elephant	0.17	1.10	15.54	0.06	1.09	5.28	0.01	0.33	4.00	0.16	1.18	13.58	0.22	1.78	12.44	**10.17**
Giraffe	0.06	0.22	26.63	0.01	0.14	10.18	0.03	0.33	8.19	0.08	1.00	8.44	0.05	0.69	6.95	**12.08**
Impala	0.21	0.70	29.49	0.29	7.32	3.91	0.17	7.65	2.21	0.57	6.65	8.62	0.16	3.40	4.72	**9.79**
Kudu	0.01	0.26	2.90	0.04	0.46	8.03	0.02	0.49	4.25	0.01	0.47	2.96	0.05	0.47	9.87	**5.60**
Steenbok	0.01	0.04	13.27	0.02	0.22	10.97	0.01	0.17	4.35	0.03	0.22	11.63	0.03	0.30	11.28	**10.30**
Zebra	0.38	8.60	4.39	0.05	0.49	10.83	0.02	0.73	3.08	0.15	0.97	15.49	0.00	0.04	10.22	**8.80**

variation across individual transects but captures the temporal variation and standard error (SE_T) represented by repeating the surveys at intervals ≥ 2 days apart. The second approach we used calculates variation across each individual transect surveyed including replicated transects. This approach captures temporal and spatial variation and standard error (SE_F) by including the spatial variation represented by different transects as well as the temporal variation represented by repeating those transects but includes each repeat as a sample which incorrectly assumes independence. We found that the temporal variation represents a very small portion of the full variation, ranging from an average of 5.6% for kudu to 12% for giraffe (Table 4). Within individual concessions, temporal SE can be has high as 29.5% of the full SE (for impala in CH 1). We suggest further development of appropriate techniques is needed to correctly account for repeated survey data in these analyses. A third option of pooling repeat data into single transect data samples was not completed but would follow similar recommendations for handling repeat data for line transect analyses (Buckland et al. 2011).

We calculated strip width density for all herbivores encountered for each concession surveyed during each season. Most of these estimates had unacceptably high variance and a CV > 0.50. We suggest that only those density estimates with a CV<50% be considered, acknowledging that even this is a high variance and results must be interpreted with caution. For completeness, we have presented all strip width densities along with their associated SE and CV in Appendix IV. Species density estimates with CV ≤ 0.50 are presented below, along with any associated distance-based analyses for comparison.

Density Estimates

We were able to garner sufficient data to use line transect distance analyses for only a small subset of the species and seasons, even though we aggressively pooled data where we could justify it. Additionally, variation within individual concession results for strip width analyses led to CV > 50% for many species and seasons. In general, we found that neither approach could be reliably used to estimate density for the rarer species or those that are only observed occasionally but in large herds (e.g., African buffalo).

As described in the Methods section, we pooled data across the Ngamiland concessions which allowed us to generate the more data-demanding distance-based models for density analyses. We did not have sufficient sample size to develop distance-based analyses for the Chobe concessions but did attempt to develop strip width density estimates for CH 1 and CH 2 for each species examined.

When available, we present the strip width and distance based results together for comparison. In most cases, the strip width estimate is lower than the distance analysis estimate but wide confidence intervals indicate lack of significant differences between the two. It is expected that strip width densities would underestimate true density even though we attempted to minimize this bias with a very conservative strip width of 50m on each side of the transect. Below, we present only those density estimates with CV ≤ 0.50; full results including density analyses with CV > 0.5 are available in Appendix III for the distance analyses densities and Appendix IV for the strip width densities.

Table 5. Strip width and distance-based line transect density estimates for elephants in concessions areas surveyed between 2013-2015; blank cells indicate no survey completed; dashes indicate survey completed but unable to generate density estimates within required CV or species not seen on survey.

Elephant		Dry 2013				Wet 2014				Wet 2015				Dry 2015			
		D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV
CH 1	Strip Width									-	-	-	-	2.48	1.10	12	44
CH 2	Strip Width									-	-	-	-				
NG 18	Strip Width	3.00	1.23	6	41	5.30	2.07	6	39	-	-	-	-	2.42	1.09	12	45
	Distance Ana.	3.14	0.96	11	31	3.14	0.96	12	34	-	-	-	-	-	-	-	-
NG 19	Strip Width	2.53	0.76	10	30	1.99	0.75	6	37	3.67	1.34	12	36	0.80	0.33	12	41
	Distance Ana.	-	-	-	-	1.86	0.79	4	42	2.90	1.53	7	53	1.27	0.57	4	45
NG 33/34	Strip Width	3.70	1.69	12	46	-	-	-	-	-	-	-	-	3.13	1.18	12	38
	Distance Ana.	6.05	2.29	5	38	0.45	0.14	4	31	-	-	-	-	4.87	1.62	13	33
NG 41	Strip Width	1.29	0.39	11	30	-	-	-	-	0.91	0.42	12	46	4.59	1.78	12	39
	Distance Ana.	3.25	1.01	37	31	-	-	-	-	-	-	-	-	6.76	1.96	10	29

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

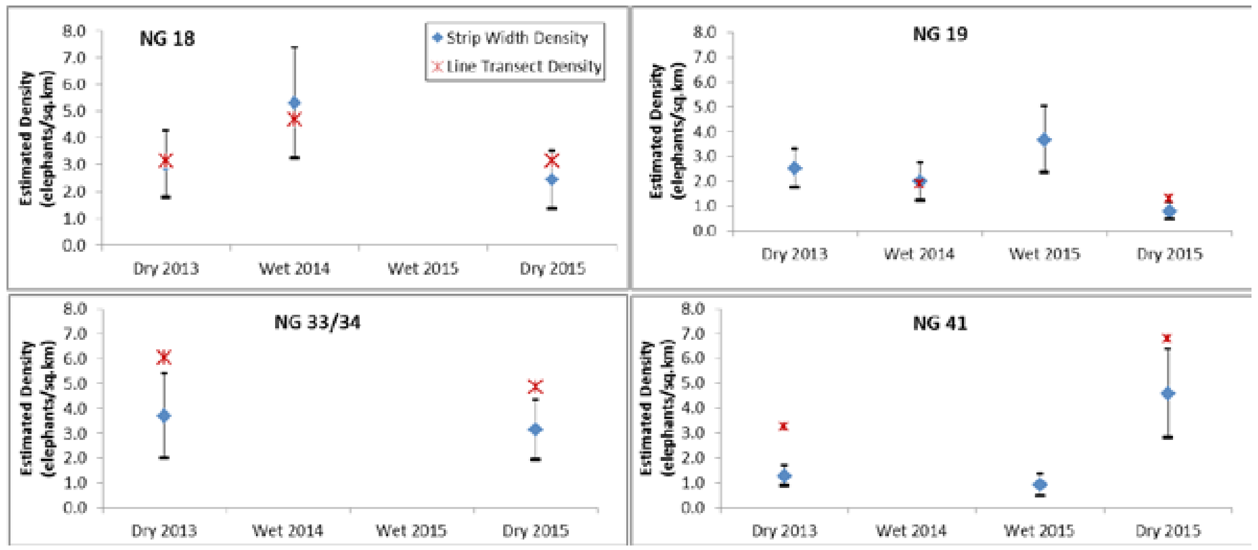

Figure 7. Strip width and distance-based density estimates for elephants in each of 4 Ngamiland concessions from surveys conducted between 2013-15; Standard error intervals shown for strip width density estimates.

Elephant

Elephants were seen in all concessions on every survey effort with the exception of in CH 1 during the 2015 wet season surveys. They represent the second most commonly seen species on the surveys, with 1,635 elephants counted over the 4 surveys from 2013-2015. Of these, 837 elephants (51%) were counted within 50m of the transect and included in the various density calculations (see Appendix X for count breakdowns).

We were able to generate reasonable seasonal density estimates for a number of concessions using both strip width and line transect approaches (Table 5). In general, more elephants were seen during the dry season in most concessions (Figure 7) and we were able to generate acceptable line transect or strip width densities estimates for each of the NG concessions during each dry season with the exception NG 19 in 2013. Dry season densities range from 1.27 elephants/sq. km in NG 19 (2015) to 6.8 elephants/sq. km in NG 41 (2015). Wet season data for elephants are sparse, with available wet season density estimates ranging from 0.45 elephant/sq.km in NG 33/34 (2014) to 5.3 elephants/sq.km in NG 18 (2014). Given the broad confidence intervals, notable trends in seasonal abundances across the concessions are not obvious (Figure 7).

Table 6. Strip width and distance-based line transect density estimates for giraffe in concessions areas surveyed between 2013-2015; blank cells indicate no survey completed; dashes indicate survey completed but unable to generate density estimates within required CV of 0.5 or the species was not seen on the survey.

Giraffe		Dry 2013				Wet 2014				Wet 2015				Dry 2015			
		D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV
CH 1	Strip Width									0.65	0.69	6	107	0.46	0.22	12	48
CH 2	Strip Width									-	-	-	-				
NG 18	Strip Width	2.66	0.88	6	33	1.15	0.55	6	48	2.53	1.10	9	43	0.37	0.14	12	38
	Distance Ana.	3.15	0.83	42	26	0.62	0.21	6	33	-	-	-	-	-	-	-	-
NG 19	Strip Width	-	-	-	-	-	-	-	-	-	-	-	-	0.71	0.33	12	47
	Distance Ana.	-	-	-	-	-	-	-	-	-	-	-	-	1.06	0.41	13	39
NG 33/34	Strip Width	1.28	0.42	12	33	-	-	-	-	2.29	0.78	12	34	2.27	1.00	12	44
	Distance Ana.	1.47	0.44	14	30	0.88	0.31	3	36	1.94	0.68	5	35	2.92	0.88	14	30
NG 41	Strip Width	-	-	-	-	-	-	-	-	1.07	0.53	12	49	1.60	0.69	12	43
	Distance Ana.	0.03	0.20	6	30	-	-	-	-	-	-	-	-	1.82	0.68	6	37

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

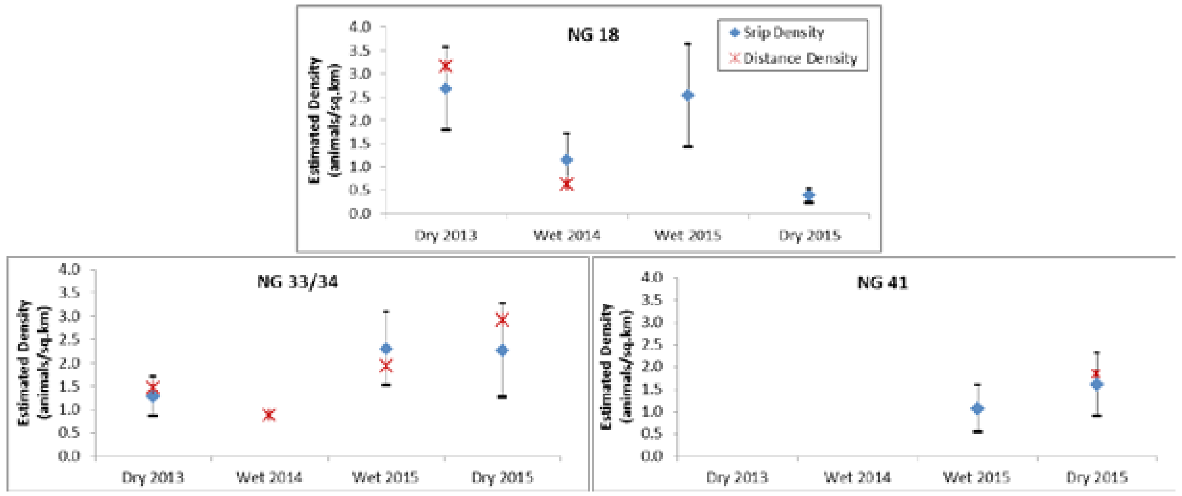

Figure 8. Strip width and distance-based density estimates for giraffes in each of 4 Ngamiland concessions from surveys conducted between 2013-15; Standard error intervals shown for strip width density estimates.

Giraffe

Giraffe were observed in all concessions and during all seasons the surveys were conducted. A total of 801 giraffe were recorded between 2013 and 2015. Of these, 403 (50%) were within 50m of the transect and were used in the various strip width density calculations (Table 6, Figure 8). Though sample sizes are relatively small, we were able to develop both strip and distance-based density analyses for some concessions during some seasons (Figure 8). As expected, most distance-based estimates are higher than the strip densities though not significantly based on these data. There is a tendency in the data for higher counts during the dry season as compared to the wet season, possibly due to the influence of foliage making detectability more difficult in the wet seasons. We are able to get obtain density estimates using both approaches for NG 19 during the dry season of 2015, as well as a strip width density for CH 1 during that same season (Table 6).

Giraffe counts are nearing the lower threshold for obtaining reliable density estimates, as evidenced by the relatively high CV values on both strip width and the few distance-based density estimates we obtained.

Table 7. Strip width and distance-based line transect density estimates for impala in concessions areas surveyed between 2013-2015; blank cells indicate no survey completed; dashes indicate survey completed but unable to generate density estimates within required CV of 0.5 or the species was not seen on the survey.

Impala		Dry 2013				Wet 2014				Wet 2015				Dry 2015			
		D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV
CH 1	Strip Width									-	-	-	-	1.63	0.70	12	43
CH 2	Strip Width									-	-	-	-				
NG 18	Strip Width	13.06	3.39	6	26	15.98	3.48	6	22	20.49	6.10	9	30	16.53	7.32	12	44
	Distance Ana.	19.31	3.74	6	19	-	-	-	-	22.81	11.21	5	49	-	-	-	-
NG 19	Strip Width	32.80	10.25	10	31	13.61	4.65	6	34	28.41	6.83	12	24	22.81	7.65	12	34
	Distance Ana.	17.00	10.08	7	25	20.02	7.08	18	33	38.07	13.19	4	35	29.86	10.22	4	34
NG 33/34	Strip Width	35.78	6.38	12	18	6.60	1.17	6	18	27.06	6.62	12	24	29.60	6.65	12	22
	Distance Ana.	38.42	6.69	7	17	8.66	2.57	30	30	35.27	13.72	4	39	32.79	12.08	3	37
NG 41	Strip Width	10.66	2.89	11	27	-	-	-	-	10.77	4.30	12	40	15.99	3.40	12	21
	Distance Ana.	12.51	5.90	5	47	-	-	-	-	-	-	-	-	23.10	9.75	4	42

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

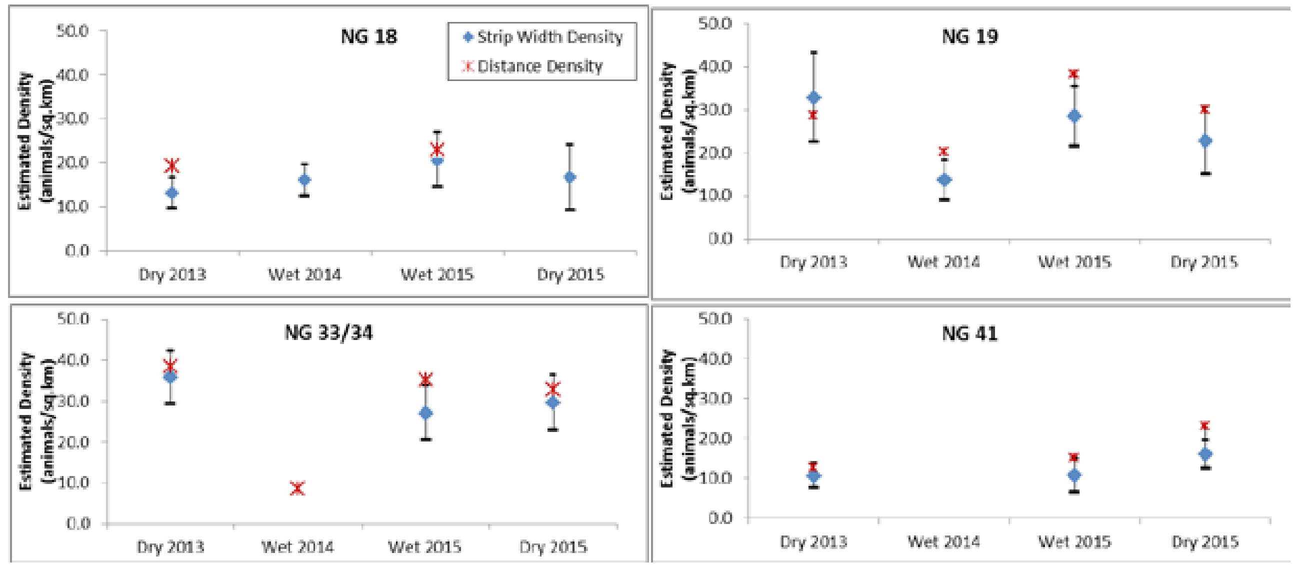

Figure 9. Strip width and distance-based density estimates for impala in each of 4 Ngamiland concessions from surveys conducted between 2013-15; Standard error intervals shown for strip width density estimates.

Impala

Impala are the most common species observed across all or most concessions. We counted a total of 10,558 impala between 2013-2105. Of these, 6,476 (61%) were within 50m of the transect and were included in the various strip width density calculations. There tended to be higher numbers observed during dry seasons than during wet seasons.

Highest densities of impala appear to be found in NG 19 and NG 33/34 (Table 7, Figure 9). We believe the consistently lower densities estimated in the wet season 2014 is likely a sampling error with lower field staffing that season resulting in lower detection rates.

We were able to generate a single density estimate for CH 1, in the 2015 dry season.

Table 8. Strip width and distance-based line transect density estimates for kudu in concessions areas surveyed between 2013-2015; blank cells indicate no survey completed; dashes indicate survey completed but unable to generate density estimates within required CV of 0.5 or the species was not seen on the survey.

Kudu		Dry 2013				Wet 2014				Wet 2015				Dry 2015			
		D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV
CH 1	Strip Width									-	-	-	-	0.55	0.26	12	46
CH 2	Strip Width									-	-	-	-				
NG 18	Strip Width	2.00	0.88	6	44	0.62	0.41	6	66	1.03	0.46	9	44	1.53	0.46	12	30
	Distance Ana.	2.77	0.61	18	22									-	-	-	-
NG 19	Strip Width	1.51	0.45	10	30	-	-	-	-	1.45	0.46	12	32	2.05	0.49	12	24
	Distance Ana.	1.01	0.35	8	34									2.08	0.91	4	44
NG 33/34	Strip Width	2.76	0.87	12	31	0.40	0.16	6	40	0.96	0.33	12	35	1.41	0.47	12	33
	Distance Ana.	2.33	1.14	4	49									1.32	0.57	6	43
NG 41	Strip Width	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Distance Ana.	-	-	-	-									-	-	-	-

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

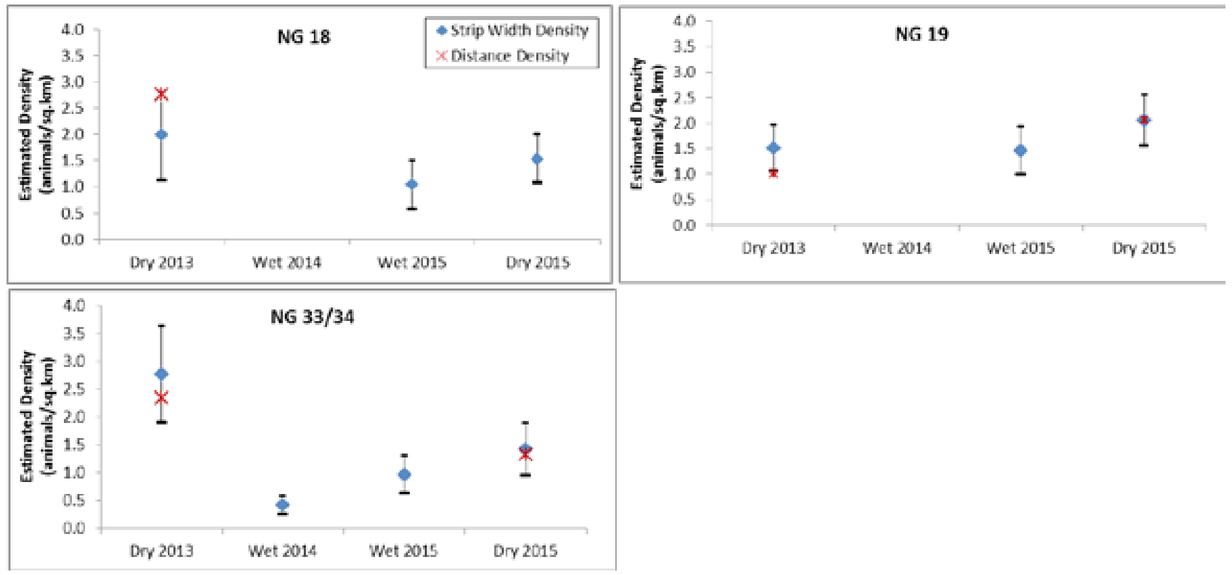

Figure 10. Strip width and distance-based density estimates for kudu in each of 3 Ngamiland concessions from surveys conducted between 2013-15; Standard error intervals shown for strip width density estimates.

Kudu

Kudu were observed more often during the dry seasons compared to the wet seasons, and were seen across all concessions though not in every season (e.g., not seen in NG 41 during the wet seasons). Across the 4 survey efforts from 2013 through 2015, we counted a total of 612 kudu. Of these, 393 (64%) were seen within 50m of the transect and available to strip width density estimates. Estimated kudu densities are lower in the wet seasons (where estimates could be made) than in the dry season though several estimates could not be generated within the CV of 0.5 (Table 8, Figure 10). We had insufficient data to generate density estimates for NG 41 and only a single estimate for the Chobe concessions and few estimates during the wet season.

Table 9. Strip width and distance-based line transect density estimates for steenbok in concessions areas surveyed between 2013-2015; blank cells indicate no survey completed; dashes indicate survey completed but unable to generate density estimates within required CV of 0.5 or the species was not seen on the survey. tance analysis; CV is the % Coefficient of Variation.

Steenbok		Dry 2013				Wet 2014				Wet 2015				Dry 2015			
		D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV
CH 1	Strip Width									-	-	-	-	-	-	-	-
CH 2	Strip Width									0.38	0.16	4	41				
NG 18	Strip Width	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Distance Ana.	-	-	-	-									-	-	-	-
NG 19	Strip Width	-	-	-	-	-	-	-	-	-	-	-	-	0.42	0.17	12	39
	Distance Ana.	-	-	-	-									0.65	0.26	5	40
NG 33/34	Strip Width	1.07	0.33	12	31	-	-	-	-	0.25	0.07	12	29	0.77	0.22	12	28
	Distance Ana.	2.11	0.98	4	46									1.33	0.30	7	22
NG 41	Strip Width	0.48	0.20	11	42	-	-	-	-	0.47	0.14	12	29	1.03	0.30	12	29
	Distance Ana.	0.94	0.46	4	49									1.92	0.84	4	44

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

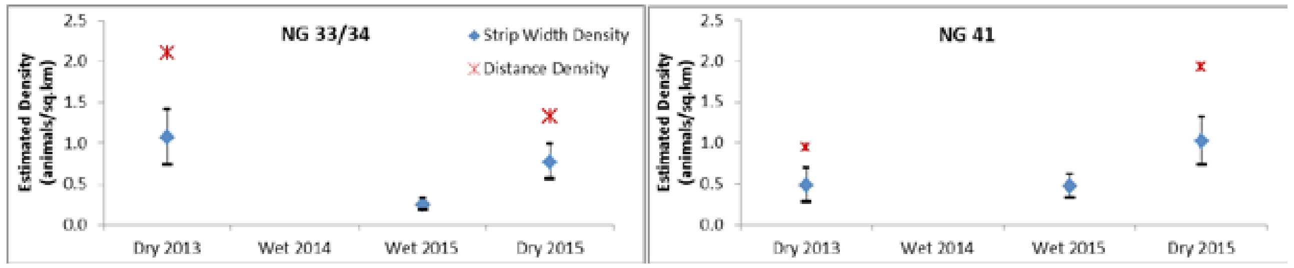

Figure 11. Strip width and distance-based density estimates for steenbok in each of 2 Ngamiland concessions from surveys conducted between 2013-15; Standard error intervals shown for strip width density estimates.

Steenbok

Steenbok were infrequently observed but widely dispersed and we counted the species in most concessions across both wet and dry seasons. Counts are generally higher in the dry season than in the wet season. We counted a total of 174 steenbok over the 4 surveys between 2013-2015. Of these, 144 (83%) were observed within 50m of the transect.

For most survey efforts, we were unable to generate density estimates though data were generally sufficient in both NG 33/34 and NG 41 in 3 of 4 survey seasons (Table 9, Figure 11). For these areas, we generally see lower estimated densities in the wet season compared to the dry season. We also see substantially higher densities estimated by the distance-based method than by strip width, as can be expected. We were able to generate a single density estimate for the Chobe concessions and were successful in both distance-based and strip width density estimates for NG 19 in the 2015 dry season.

Table 10. Strip width and distance-based line transect density estimates for warthog in concessions areas surveyed between 2013-2015; blank cells indicate no survey completed; dashes indicate survey completed but unable to generate density estimates within required CV of 0.5 or the species was not seen on the survey.

Warthog		Dry 2013				Wet 2014				Wet 2015				Dry 2015			
		D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV
CH 1	Strip Width									-	-	-	-	0.72	0.23	12	32
CH 2	Strip Width									-	-	-	-				
NG 18	Strip Width	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Distance Ana.	-	-	-	-									-	-	-	-
NG 19	Strip Width	0.86	0.41	10	48	1.04	0.58	6	56	0.73	0.29	12	40	1.17	0.37	12	32
	Distance Ana.	0.95	0.39	6	41									1.55	0.60	4	39
NG 33/34	Strip Width	1.32	0.43	12	33	0.13	0.12	6	89	0.21	0.10	12	47	0.90	0.20	12	22
	Distance Ana.	1.19	0.68	4	57									1.14	0.34	5	30
NG 41	Strip Width	0.56	0.27	11	48	1.85	1.15	6	63	1.42	0.49	12	34	1.31	0.54	12	41
	Distance Ana.	-	-	-	-									-	-	-	-

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

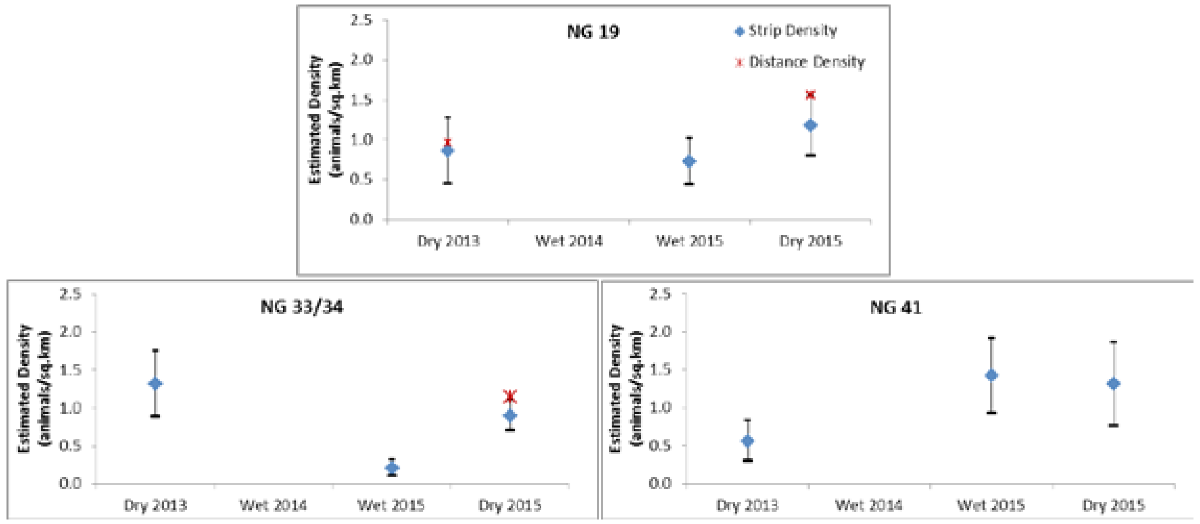

Figure 12. Strip width and distance-based density estimates for warthog in each of 3 Ngamiland concessions from surveys conducted between 2013-15; Standard error intervals shown for strip width density estimates.

Warthog

Warthog were observed in all concessions and seasons though tended to be more frequently see in the dry seasons as compared to the wet seasons. We counted 439 warthogs, of which 300 (68%) were within 50m of the transect. Sample sizes were higher in the Ngamiland concessions and we were able to generate strip width density for all seasons for NG 19, NG 33/34 and NG 41 but no density estimates were generated with a CV of .50 or less for NG 18 (Table 10). A single density estimate is available for CH 1 in the 2015 dry season. We were also able to generate distance-based estimates in the dry seasons for NG 19 and NG 33/34. Generally, there appears to be a tendency for dry season estimated densities to be higher than wet season estimates. Across the concessions, estimated densities are similar, ranging from 0.9 – 1.15 animals/sq.km in the dry season.

Table 11. Strip width and distance-based line transect density estimates for zebra in concessions areas surveyed between 2013-2015; blank cells indicate no survey completed; dashes indicate survey completed but unable to generate density estimates within required CV of 0.5 or the species was not seen on the survey.

Zebra		Dry 2013				Wet 2014				Wet 2015				Dry 2015			
		D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV	D	SE	DF	CV
CH 1	Strip Width									-	-	-	-	-	-	-	-
CH 2	Strip Width									-	-	-	-				
NG 18	Strip Width	-	-	-	-	-	-	-	-	-	-	-	-	1.27	0.49	11	38
	Distance Ana.	-	-	-	-	0.59	0.26	2	44	-	-	-	-	1.09	0.49	5	45
NG 19	Strip Width	-	-	-	-	-	-	-	-	4.10	1.61	11	39	2.56	0.73	11	29
	Distance Ana.	-	-	-	-	-	-	-	-	4.49	2.06	4	46	3.18	0.82	26	26
NG 33/34	Strip Width	-	-	-	-	-	-	-	-	2.54	1.14	11	45	2.66	0.97	11	36
	Distance Ana.	0.15	0.07	6	49	0.17	0.07	1	41	2.35	1.02	7	44	1.94	0.91	7	47
NG 41	Strip Width	-	-	-	-	4.87	2.16	5	44	20.51	10.10	11	49	-	-	-	-
	Distance Ana.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

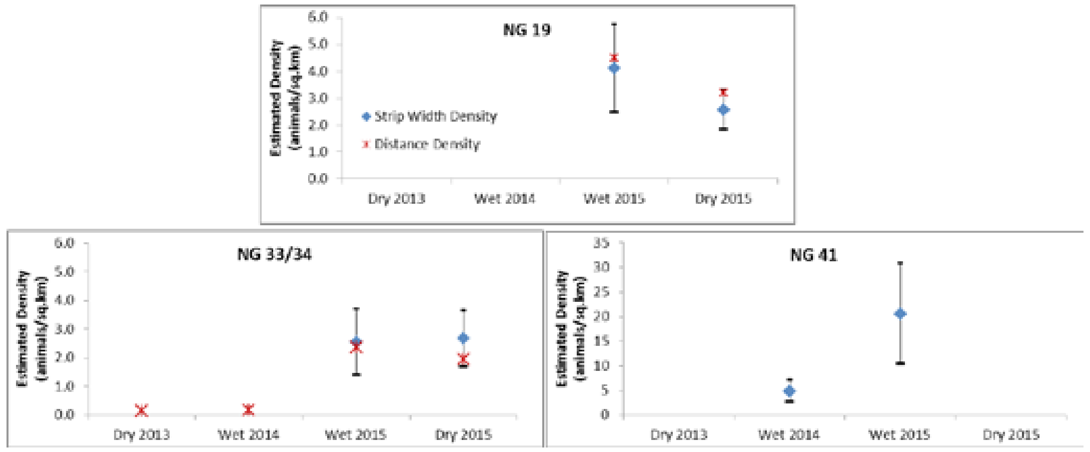

Figure 13. Strip width and distance-based density estimates for zebra in each of 3 Ngamiland concessions from surveys conducted between 2013-15; Standard error intervals shown for strip width density estimates.

Zebra

Zebra represent a commonly observed species during the surveys but the spatial distribution of zebra appears to be seasonally variable across the concessions. For example, during the 2015 wet season surveys, 569 zebra were counted in NG 41 while 140 were counted in CH 1. In the 2015 dry season, relative abundances reversed and over 900 were counted in CH 1 and less than 40 in NG 41. Over the 4 seasons spanning 2013-2015, 2,473 zebra were counted. Of these, 1,496 (60%) were within 50m of the transect and used in the various strip width density estimates. Similar to the counts, the density estimates varied markedly between seasons and concessions (Table 11). We had limited success in generating acceptable density estimates despite the generally more common occurrence and higher counts of zebra. Density estimates, particularly distance-based estimates are challenging in species that are found in herds and therefore exhibit a spatially 'clumped' distribution leading to high variance in encounter rates and (for distance analysis) group size.

Table 12. Strip width density estimates for more uncommon herbivore species counted in concessions areas surveyed between 2013-2015; blank cells indicate either no survey completed, we were unable to generate density estimates within required CV of 0.5 or the species was not seen on the survey.

Species		Wet 2014				Wet 2015				Dry 2015			
		D	SE	N	CV	D	SE	N	CV	D	SE	N	CV
AFRICAN BUFFALO													
	NG41					0.20	0.09	12	45				
DUIKER													
	CH2					0.32	0.13	4	40				
REEDBUCK													
	NG18					0.80	0.33	9	41				
HIPPO													
	NG18									1.38	0.65	12	47
	NG19					3.97	1.57	12	40	1.64	0.56	12	34
OSTRICH													
	CH1									0.36	0.18	12	49
	NG41	2.18	0.99	6	45								
TSESSEBE													
	NG33-34	0.88	0.37	6	42								
WATERBUCK													
	NG19					1.83	0.54	12	29	1.26	0.57	12	46

D = estimated density (square km), SE = standard error; DF = degrees of freedom; CV is the % Coefficient of Variation.

Additional Species

In addition to the above seven species, we observed 20 other species during the survey efforts. Most of these species were rarely seen and we did not have enough data for generating density analyses. In some instances we were able to generate a strip width density for some species for a single concession and survey effort. These include African buffalo, common duiker, common reedbuck, hippo, ostrich, tsessebe and waterbuck (Table 12). Data collected on other herbivores including eland, red lechwe, roan, tsessebe and wildebeest were insufficient to allow density analyses by concession and season. At current levels of survey intensity within individual concessions, density estimates are spotty and of limited use concession population monitoring efforts except for the more common species that are widely distributed.

Adequacy of Sampling Effort and Spatial Coverage

Sampling Effort. Using the data we have collected it is possible to estimate the recommended sampling effort (distance surveyed) required to obtain density estimates with reasonable CVs. These calculations (Buckland 2011, equation 7.12) are based both on the encounter rate (groups counted/transect km) and the variability in the group size. We used this approach to estimate the total transect length (km) within each concession required to achieve a CV value of 0.5 for species which we have reasonable sample sizes (Buckland 2011, equation 7.12). These species include elephant, giraffe, impala, kudu, steenbok, warthog and zebra. Given the notable differences in detectability between wet and dry seasons, we calculated separate estimates for dry and wet seasons and based the evaluation on the 2015 data only (see Appendix V). To make recommendations on transect length modifications, we calculated the average length of transects (and maximum length across species considered) recommended for each concession and season to achieve a CV of 0.5 as well as a CV of 0.25, based on the recommendations for elephant, giraffe, impala, kudu and zebra (Table 13). For most concessions, higher effort is generally required in the wet season compared to the dry given the smaller numbers of most species counted during the wet season. The effort (length of transect surveyed) within each concession is reported for the dry and wet seasons of 2015 as the cumulative length across the 3 replicate surveys completed each season. These cumulative numbers are provided as a metric for comparison with the recommended effort.

Table 13. Following Buckland (2011), the estimated minimum sampling effort (i.e., transect length) needed to obtain a CV of density of 0.5, shown as the average (and maximum) recommendation for elephant, giraffe, impala kudu and zebra for each concession using the data from the wet and dry 2015.

	Recommended Survey Effort (Km) Ave (Max) for Wet 2015		Survey effort (km) Wet 2015	Recommended Survey Effort (Km) Ave (Max) for Dry 2015		Survey effort (km) Dry 2015
	CV=0.5	CV=0.25		CV=0.5	CV=0.25	
NG 18	536 (1144)	2144 (4577)	174	190 (341)	758 (1363)	269
NG 19	188 (465)	754 (1862)	234	153 (246)	613 (984)	239
NG 33-34	124 (251)	494 (1003)	239	118 (246)	472 (983)	233
NG 41	186 (285)	745 (1141)	253	205 (570)	820 (2279)	244
CH 1	-	-	186	239 (498)	955 (1992)	306

Table 14. Average spatial representation of concession areas based on a 2km buffer around each transect calculated from surveys completed between 2013-2015.

Concession	Concession Area (sq. km)	2 km Buffer of Transects	% Concession
CH1	1536	262	17
CH2	1432	226	16
NG18	1751	135	8
NG19	171	106	62
NG33/34	922	175	19
NG41	2187	234	11

These should be used as guidelines, and Buckland (2001) recommends these are likely minimum distances needed to obtain the indicated CV. The 0.5 value for the CV is quite high compared to CV values that may be more acceptable such as setting a goal of CV = 0.25, but may be a realistic goal based on the data included in this report. Decreasing the CV by half (0.25) requires a four-fold increase in distance, and the transect length recommended for any CV can be approximated using the following equation generated from our data:

$$L_{target} = L_{CV0.5}(0.5/CV_{target})^2$$

Where L is the recommended transect length and 'target' indicates the target CV for which the recommended transect length is calculated. Using this ratio, the transect length can be estimated for any CV, but substantial drops in the CV goal will entail very significant increases in the transect length required.

In addition, refining sampling effort needs to also consider the important assumptions made in the analyses. These assumptions include, most critically, that the data collected represents a random sample of the population of interest. We suggest that the size of each concession and spatial distribution of existing transects relative to major habitats or population distribution patterns are extremely important considerations. In Namibia, it is assumed that extrapolation of densities can be justified up to 2km from the transect routes (Heinemeyer et al. 2013) leading to population estimates for 50-75% of conservancy areas surveyed. If we assumed a similar extrapolation extent, existing survey efforts and associated extrapolations would only be less than 20% of most concessions with the exception of NG 19, which has good coverage at 62%. Spatial coverage of NG 18 at 8% and NG 41 at 11% is particularly worrisome, but all concessions except NG 19 are poorly represented spatially by the existing survey effort (Table 14).

Demographic Analyses Results

We undertook exploratory analyses of the demographic data collected in the surveys. These analyses are used to assess the utility of the demographic data to provide insights into population dynamics of each species and to develop recommendations on improving data collection and its potential uses in population monitoring.

Impala

Over four seasons, 1,025 of the 1,259 groups of impala seen were identified and categorized into age-class and sex (Appendix II). The gender ratio for a stable impala population is 1:1.1 total males to total females (2001 Grootfontein Agricultural Development Institute). Because of the difficulty to differentiate between female and male impala during the first three months after birth, we compared the adult and subadult males to adult and sub-adult females to determine sex ratio.

The sex ratio of impala for each concession for each season fluctuates (Table 15). The fluctuations between years and concessions could be due to environmental variables, or could be due to other factors. The decrease during the wet season may be caused by a decrease in sightability, where it is harder to see an entire herd due to the larger amount of vegetation constricting a clear view. The fluctuation of the populations could also be due to different times of the year. Gender ratio comparisons should occur during the same season each year. Looking at the dry seasons of 2013 and 2015 we can see much more stable numbers.

Table 15. Ratio of total female impalas per one male impala across all concessions and seasons.

Concession	Dry 2013	Wet 2014	Wet 2015	Dry 2015
NG18	2.75	1.24	0.69	2.07
NG19	2.47	3.33	1.82	2.72
NG33/34	1.59	1.42	0.89	0.95
NG41	2.13	0.35	0.54	2.55
CH1			0.00	1.33
Total	1.97	1.66	1.09	1.84

Sub-adult females cannot be reliably distinguished from adult females, so, following Owen-Smith & Mason (2005), total sub-adults were calculated by assuming an even sex ratio and by doubling the number of subadult males. Adult females were calculated by then subtracting the number of sub-adult females from the adult female population number. Age class comparisons between adult females and juveniles range from season to season and by concession (Table 16). Impala normally give birth right after the first rains, which usually occur in November, which is at the end of our dry season surveys. The high number of impala births in such a short time is easy prey for predators, so there is normally a large drop in calves born and calves who make it to their first year. The wet season of 2014 is higher than most other ratios across seasons and concessions, and this may be due to the fewer transects driven and less data to work with, resulting in abnormally high numbers.

Table 16. Ratio of juveniles per one adult female impala across concessions and seasons.

Concession	Dry 2013	Wet 2014	Wet 2015	Dry 2015
CH1	-		0.00	0.00
CH2	-		0.00	NA
NG18	0.11	0.25	0.05	0.08
NG19	0.10	0.24	0.14	0.06
NG33/34	0.15	0.27	0.35	0.13
NG41	0.05	0.00	0.00	0.00
Total	0.11	0.24	0.17	0.06

Kudu

Of the 208 sightings of kudu over four seasons, 180 were identified into a sex and age class for the entire group. Male kudu become sexually mature between 21 and 24 months, while females become sexually mature between 15-19 months. The male to female ratio for an adult population to remain stable for kudu is 1:1.4-1.8 (wildliferanching.com). The gender ratio adult and sub-adult kudu for each concession suggest, while there is wide variation, that the kudu populations are at a stable ratio (Table 17).

Table 17. Ratio of adult and sub-adult female kudu per one adult or sub-adult male across all concessions and seasons.

Concession	Dry 2013	Wet 2014	Wet 2015	Dry 2015
NG18	7.60	1.33	-	4.07
NG19	1.56	0.25	1.60	1.43
NG33/34	3.71	1.00	1.00	1.50
NG41	1.00	-	1.88	0.62
CH1			3.00	1.00
Total	3.30	0.83	1.33	1.63

The juvenile:adult female ratio is variable across concessions and seasons, ranging from 0 juveniles to 0.45 juveniles:1 adult female (Table 18). The low ratio between adult female kudu and juveniles may be due to the behavioral traits of the species. Female kudu will hid their young when they are first born in tall grass or in dense brush. This could lead to juveniles being under sampled. While on transect, it is difficult to remain with a herd for a long period or time. Recording sex and age of species while not on transect may allow us to spend more time with individuals and may allow us to count more juveniles.

Table 18. Ratio of juveniles per one adult female kudu.

Concession	Dry 2013	Wet 2014	Wet 2015	Dry 2015
CH1	-		0.00	0.00
NG18	-	-	0.00	
NG19	0.18	0.25	0.00	0.04
NG33/34	0.45	0.00	0.19	0.05
NG41	0.18	0.20	0.00	0.00

Giraffe

Of the 304 sightings of giraffe over the four seasons, 237 identified the age and sex of the individuals. The gender ratio for all ages across seasons and concessions seems constant, comparing to the natural gender ratio for giraffe at 1:0.83.

Looking at both the gender ratio for the giraffe populations and only adult giraffe the ratios suggest that ratio between males and females across concessions should be further monitored for potential declines (Table 19). While density estimates for giraffe are relatively stable besides NG18 (Figure 8), if there is an unbalanced gender ratio in these population it is possible numbers could decrease.

Table 19. Ratios of total female giraffes per male giraffe across concessions and seasons.

Concession	Dry 2013	Wet 2015	Dry 2015
CH1	N/A	0.40	1.07
NG18	1.32	1.42	1.00
NG19	1.27	1.60	0.92
NG33/34	0.50	0.77	0.91
NG41	0.31	0.50	0.84
Total	0.80	0.85	0.93

Giraffe have no mating season however it is common for them to mate during the wet season. The gestation of giraffes is approximately 15 months however calves less than a year old are normally isolated from herds and kept hidden by their mothers, and therefore under-sampled (Owen-Smith Mason 2005); this could significantly influence the juvenile:adult female age ratios recorded during the surveys (Table 20). Spending more time identifying the sex and age class of giraffes, outside of transects, may allow us to collect more robust data.

Table 20. Ratio of juveniles per one adult female giraffe.

	Dry 2013	Wet 2014	Wet 2015	Dry 2015
CH1			0.00	0.36
NG18	0.40	0.00	0.00	0.00
NG19	0.27	NA	0.00	0.44
NG33/34	0.20	0.00	0.06	0.11
NG41	0.00	0.30	0.00	0.12
Total	0.28	0.12	0.04	0.18

Steenbok

The natural gender ratio for steenbok is 1:1 (Table 21). In CH1, NG18, NG19 in wet season 2015 and NG18 in the dry season of 2015, only males were seen. Steenbok breed year round, however most fawns are born between November-December and suckle for 3 months. Therefore, the lack of females seen in the wet season could be due to females more cautious with their offspring. This might also explain the decrease of steenbok in the wet season of 2015, as the decline was not from decrease in population, but decrease in female sightings. No juveniles were recorded in the four seasons of data collection, and due to the difficulty of distinguishing between sub-adults and adults, no sub-adults were recorded.

Table 21. Ratio of total female giraffes per male steenbok across all concessions and seasons.

Concession	Dry 2013	Wet 2015	Dry 2015
CH1	NA	0.00	1.00
NG18	1.00	0.00	0.00
NG19	2.00	0.00	1.00
NG33/34	1.07	0.67	1.60
NG41	0.67	0.50	0.93
Total	1.00	0.32	0.88

Discussion and Recommendations

Long-term sustained wildlife monitoring is a prerequisite for effective wildlife management and conservation. Maintaining wildlife population monitoring across large and remote landscapes is challenging and aerial transect surveys is one approach that provides a practical means to repeatedly survey large areas without roads (Norton-Griffiths 1978; Hayek & Buzas 1997; Miller et al. 1998). Botswana has used fixed-wing aerial strip transect surveys to estimate wildlife density and abundance nationally and in northern Botswana since the 1970s (Chase et al. 2011) with recent surveys completed in 2015 (M. Chase, personal communication).

This report presents the first documented ground-based density estimates for a diversity of herbivore species in northern Botswana that we are aware of. The Botswana Predator Conservation Trust has undertaken ground-based transect surveys for multiple years in Ngamiland 33 as part of their long-term research efforts (J. McNutt, personal communication) and preliminary density estimates are available on their website (www.bpctrust.org). They are currently updating these analyses, which were unavailable at the writing of this report except estimates for impala (K. Golabek, personal communication) that were similar to our estimates in the same area.

The density estimates we report from the ground-based transects are notably higher than density estimates from aerial surveys for the same or similar areas (see Chase et al. 2011). We do not have long-term ground-based data to assess population trends, and the higher ground-based estimates do not contradict the suggested trends in wildlife populations revealed in long-term aerial surveys (Chase 2011). There may be multiple reasons for the differences in population estimates drawn from the ground-based and aerial survey approaches, as described below.

Our ground-based transect surveys are limited to existing roads and tracks and for many concession areas cover a small percent of the available habitat (Table 14). In some cases, these roads or tracks may have been developed primarily because high quality local habitat conditions represented excellent wildlife viewing or hunting opportunities for the concessions. As a result, our transects may be primarily in high density areas of each concession and our resulting density estimates reflect this. Alternatively, the aerial surveys have the ability and are designed to sample across the full extent of the concession areas and so include sampling of all habitats available including low density areas so that overall density estimates are lower.

Sightability, either from the ground or air, is a significant issue that must be addressed in developing density estimates. It is not unusual for ground-based densities to be notably higher than aerial surveys, and sightability from the air has been identified as the primary factor underlying the differences (Jachmann 2002). This may be an underlying reason that several authors have noted that aerial census data are prone to underestimate large mammal populations (Bouché et al. 2012, Caro et al. 2000; Stoner et al. 2006). The line transect data we collected allowed us to examine some key factors affecting sightability (e.g., distance from road, vegetation). These were evaluated through the use of distance-based analyses, and the sightability assessment was also used to develop conservative strip width definitions (50m each side of transect) for the strip transect density analyses. Thus, the large differences in the estimated densities may be partially due to differences in sightability between the two types of survey approaches and are further enhanced by our conservative estimate of strip width.

Despite the differences in density, multiple approaches to monitoring wildlife is desired and recommended (Caro et al 2008) as they provide different resolutions of temporal and spatial scales, unique insights into the dynamics of the wildlife populations and each boasts its own suite of methodological strengths and weaknesses. Driving transects challenge multiple assumptions of population monitoring because these transects are almost exclusively along pre-existing tracks or road. Thus, these routes are not randomly or systematically placed on the landscape, and they may influence the local distribution and abundance of wildlife due to their presence or because they allow or attract human use. Still, vehicle-based monitoring represents a feasible and economical approach to wildlife monitoring that has been used successfully for long-term monitoring of population trends in other African landscapes (Caro 2011, Heinemeyer, 2012, 2013, 2014, www.nacso.org.na). Careful development, implementation and on-going quality control of the survey effort can lead to effective monitoring of population trends through time. Regardless of the approach to monitoring (e.g., aerial, vehicular, foot surveys), the true value of the data is almost always in the long-term collection of comparable data over several years. Thus, the aerial surveys undertaken since the 1970s in northern Botswana represent an invaluable source of population monitoring if the methodologies are defensible and comparable through years.

The DADS ground-based, driving transects should provide insights into the population dynamics that complement the aerial surveys, and could potentially be used to calibrate aerial census results (Caro, 2012) In time, the on-going MOMS monitoring information should also be incorporated into the on-going management and assessment of wildlife populations in the region, adding additional perspective and information to the management and conservation of wildlife. Such an approach for estimating terrestrial wildlife abundance while integrating local people into scientific and conservation projects may also assist with elevating the vested interest in wildlife conservation by the people who are both influential and affected by these efforts (Ransom, 2012).

Population density estimates, themselves or even coupled with demographic data, provide limited information on the underlying drivers of population trends. Placing population information in the context of landscape and habitat conditions, dynamics and changes would provide the kind of insights needed to make meaningful management decisions now and into the future (Morellet 2007). This is increasingly true as potentially subtle, unforeseen or novel shifts in ecological dynamics arise due to changing climate conditions, expanding human impacts and other emerging threats.

Based upon the data and the data analyses we have completed on the 2013-2015 survey data, we suggest a number of ways to improve the efficiency and effectiveness of the DADS effort. We present these recommendations to encourage further review and discussion on the current protocols in the spirit of on-going adaptation of the regional efforts.

Sampling Effort

A critical determinant to the successful monitoring of any species is obtaining sufficient data to complete density and demographic monitoring through time and space. We found data collected through our effort are marginal or insufficient to provide reliable estimates of density or demographics for most or all species of interest. We calculated an estimate of effort, measured in survey length, required for key species to achieve desired levels of variation based on the data collected in the 2015 dry season and found that current distances are generally insufficient to achieve CV $\leq$ 0.5. We also found that most of the variation in the density estimates is due to spatial variation rather than temporal variation. Additionally, most concession survey efforts are highly clumped to a small portion of the concession area. Extrapolating estimated density to the larger concession requires ensuring that the proportion of the concession sampled is representative of the concession-level populations, something difficult to do. To enhance and refine the survey effort to better capture the important sources of variation and to achieve a more consistently acceptable coefficient of variation and representative density estimates, we recommend the following:

Increase the concession-level of effort (survey km) based on Table 13 and Appendix III Table A- 8 or use the equation provided in Adequacy of Sampling Effort section to estimate effort needed for the desired CV. This effort should include considerations about the spatial coverage of existing concession survey efforts. Focus available sampling effort first on spatially representative transects by increasing the number of transects to achieve desired sampling effort rather than on repeating surveys along fewer transects.

Spatially stratify sampling effort when feasible to capture major landscape variation patterns in expected species distributions across concessions. This includes reconfiguring existing transects to avoid looping which creates redundancies in spatial coverage. A possible 'rule of thumb' may be avoid transect routes or sections of transect routes placed within 4km of each other assuming a 2km extrapolation limit. Improving spatial representation will also require establishing new transects in areas not currently covered by the surveys for most concessions.

While some concession efforts could continue replicating transects to evaluate temporal variance, our assessment indicates that temporal variation at the scale of days (as in current protocols) is minor compared to spatial variation in species densities, which dominates the variation components. This is true even though the current spatial distribution of transects is highly clumped at the concession-level for most concessions. We suggest that seasonal or year-to-year replicate surveys capture temporal variance at more meaningful timescales.

Spatial stratification should strive to represent coarse-scale landscape habitats (e.g., major types of river corridors, savannahs, forest types) and does not necessarily need to encompass the entire concession, particularly as this is likely not feasible for several concessions given the lack of access. Current configuration of survey routes should be evaluated for representativeness and therefore appropriateness for extrapolating densities. For example, if most of transects are conducted along rivers, it is inappropriate to extrapolate those densities to the arid regions of the concession.

Consistency and Training

Given the diversity of entities undertaking the survey efforts across a multitude of concession areas, it is recommended that consistency in methods is critical both within each effort and, more challenging, across efforts to allow comparable data to be collected. This includes level of training undertaken by data collectors, level of staffing on surveys, and consistency in inclusion of concession staff or local experts that ensure routes are known and repeated. These include:

1) Based on our experience, we suggest standardizing the survey team to consist of four people: a driver, front passenger responsible for looking for animals straight ahead, sighters on each side of the vehicle responsible for looking for animals ahead and to the side. Having more or less people results in inefficient surveys and may contribute to increased variability in data.

2) All personnel should be rigorously trained in the field techniques and checked throughout the season to correct any deviations in data collection. A field training manual should be developed and used by all survey efforts to ensure consistent methods and data collection. *It is critical to recognize that even seemingly small field errors in distance estimates and compass readings translate into large potential error in the analyses.*

Matching Field Techniques to Data Analyses

We have evaluated the data collected in multiple ways to understand the underlying drivers of variation and the limits and challenges for estimating densities. We believe the most critical improvement would be increasing the distance surveyed within each concession and doing this in a spatially appropriate manner. Distance or sampling effort is limited by capacity (i.e., time), so we have evaluated how field techniques may be refined to create efficiencies in data collection that may then translate into greater capacity to increase sampling effort. These also critically consider what types of analyses may be feasible for different species and include, for example, simpler and faster field methods for those species in which line transect analyses are not likely feasible. Based on these assessments, we make the following recommendations to enhance the ability to generate rigorous density estimates for herbivores useful for monitoring:

1) Standardize all concession surveys to use a common set of field techniques, data collection standards and training. This may allow pooling data across concessions for the development of detection probability function models for more uncommon species and potentially enable a wider suite of species to be analyzed using the more rigorous line transect approach to density estimation. For more common species, pooling data will allow more robust density estimates with lower variation. Either ORI or DWNP should be designated to collect concession-level data and oversee the pooled use of these data by an analyst qualified in to conduct the distance-based modeling.

2) Some species are so uncommon that even pooled data would be insufficient for line transect analyses. To increase field efficiencies, we recommend that field data collection can be simplified for uncommon species using modified strip transect methods which categorize observations into distance intervals rather than radial distance data through compass and laser range finder. For larger mammals, suggested intervals are: 0-50m, 50-100m, 100-200m, >200m. For small mammals (e.g., duiker, steenbok), recommend smaller intervals: 0-5m, 5-10m, 10-15m, 15-25m, 25-50m, >50m as effective density analyses must occur at smaller spatial scales given the inherent poor sightability. These data are appropriate for strip transect analyses and can be explored for line transect analyses.

3) Further increases in field efficiencies may be possible but need to be tested. Distance analyses can use interval distance data if there is high accuracy in the classification of animals and the distances are reasonable given the species considered. In our evaluation, most species distributions were reasonably binned using 25m intervals. Thus, it may be feasible to simply refine the field techniques to interval classifications for all species. We will be collecting data to explore this option in 2016.

For species for which distance analyses is desired, strive to collect a minimum of 300 observations across the areas that can be effectively pooled (i.e., adjacent concessions with similar landscape-level habitat conditions) per season. This would almost certainly require the pooling of data across different entities conducting the surveys and require a combined analysis.

Improving Demographic Data

Demographic data can provide important insights into the underlying population dynamics that contribute or define population trends. One of the criteria to include observation data in analyses of age and gender ratios is that the sex and age of all individuals within any group is determined. Any groups in which the age class and sex of even one of the individuals was not identified means the data were unusable. Because of this, many data points, especially with elephants, could not be analyzed. After initial exploratory analysis of the data, we concluded that many species' data would not accurately reflect age and gender ratios in each concession. For example, the elephant data were heavily skewed towards adult bulls, which are more solitary and easier to identify age and sex than a large breeding herd.

Our assessment of the demographic data collected suggests several options for improving our ability to meaningfully use this information in concert with density analyses:

1) If demographic classification is attempted, one must invest the time to complete a demographic classification of all individuals. For groups where this is not possible, it is likely not worth the time getting partial classifications. If this selective process leads to consistently not classifying larger groups, then this approach will also introduce significant bias and should not be used. Unbiased standardized methods need to be explored which are feasible given the extra time required to ensure all individuals are seen and classified (e.g., classify every third observation regardless of group size).

2) Review age and sex classifications to determine classifications that are both feasible and useful. For example, it is difficult to distinguish between adult and sub-adult female impala and may not be consist across surveyors nor absolutely needed to provide insights into population dynamics.

3) As with density data collection, all personnel should be rigorously trained in the field techniques and checked throughout the season to assure classifications are accurate. Demographic classification dramatically improves with field experience as long as on-going training is provided. Concession escorts or local experts are critical to ensure high quality demographic data are collected and having these experts should be required for all surveys. A field training manual should be developed and used by all survey efforts to ensure consistent methods and data collection.

4) Demographic classifications should be conducted on one transect replicate, if transect are being repeatedly surveyed each season. There is a high likelihood of classifying the same herds or individuals repeatedly within the limited time frame of replicate surveys.

5) In addition to collecting demographic data along transects, we recommend recording demographic information during opportunistic sightings using protocols that ensure these opportunistic sightings are not biased. For example, all sightings of a given species are classified on defined dates (except when potentially seeing same animals such as returning along a transect route where classification completed). This should be explored as an option for increasing sampling of demographic information, particularly if demographic classification is reduced during transect surveys due to time limitations.

6) If concession surveys become standardized with a common set of field techniques, data collection standards and training, it may be possible to pool data across regions for more rigorous analyses. DWNP should designate the collection of concession-level data and oversee the pooled use of these data by an analyst qualified in to conduct the demographic analyses or modeling.

Chapter 2: Bird Surveys

Bird populations are an aspect of the Delta's diversity that needs further research and analysis. Avian species face a wide range of threats throughout northern Botswana, in addition to global threats such as climate change and corresponding seasonal weather shifts. These concerns include habitat loss, agricultural intensification, and the effects of poaching and poisoning on larger scavenging species (Kendall and Virani 2012; Thiollay 2006). The SAREP monitoring protocols outline voluntary bird monitoring surveys to be conducted during wet and dry seasons by concessions. The objectives of these surveys include developing a Wild Bird Index (WBI) for Botswana that documents population trends over time and to increase community participation through building capacity in bird identification and awareness (Bourquin and Brooks 2013). WBIs are used to act as a barometer for the state of the environment and its changes.

Birds can act as an indicator of the general health of an ecosystem and proxies for larger changes in an environment (Sheehan et al 2010). Not only are they relatively easy to identify and survey, but they also use the landscape at a much larger scale than most other taxa, which allows birds to represent environmental changes over much broader spatial scales (Sheehan et al 2010).

The economic benefits of wildlife tourism including bird tourism, in Botswana supports the maintenance of natural ecosystem and discourages conversion to other uses such as agricultural land, especially when ensured that the surrounding communities reap those benefits (Vanderpost 2006). Human disturbance, and the resulting habitat fragmentation and edge effects, are negatively correlated to bird populations (Zhang et al. 2012). Monitoring the health of bird populations in Botswana will provide information on the state of the larger landscape. Our interviews with Community Escort Guides in the Sankuyo, Khwai and Mababe areas show that community trusts believe they would benefit from an increase in avian tourism. Avitourism has had positive economic effects across the world, including South Africa (Tauatsoala 2015, Sekercioglu 2002). The wide diversity of ecosystems that range from semi-desert to wetlands supports an impressive bird heritage that draws bird enthusiasts across the world to northern Botswana.

Methods

Three types of bird monitoring information were collected: SAREP point count surveys, Birdlife Point Count Surveys for Birds of Concern and opportunistic recording of Birds of Concern.

SAREP Point Count Bird Surveys

Point count surveys were conducted from February through April (wet season) and September through December (dry season) of 2015 (Figure 14). Methods were based on the recommendations of Bourquin and Brooks (2013). Surveys began at 06:00 and continued for two hours, some wet season transects were also surveyed from 16:00 to 18:00. Each transect has a designated route and is conducted by four to five people in a vehicle. After arriving at the first point, pertinent information is recorded; observers' names, date, time, and weather, including the wind speed, cloud cover and temperature. (See Appendix VI for Survey Data Sheet).

Basic training on bird species identification, including familiarization with the appearance of common birds was conducted prior to survyes. The extensive knowledge of Escort Guides and Round River staff present on the transects helps ensure accurate identifications. Each line transect had nine to eleven points where visual and audio signs of birds were recorded. Point-count durations were eight minutes in Sept-Dec 2015 and five minutes between Feb-May 2015. Distance between point counts varied, with 200m between each point count in Feb-May 2015 and 1km during Sept-Dec. Three to four trained team members searched for avian species in the surrounding environment, while one person recorded the data and kept track of the time. When a bird was spotted, information entered into the data sheet included the species, number and sex of birds, their current behavior, and habitat. Our behavior codes were limited to Flying, Grooming, Eating, Roosting, Swimming, and Other. Habitat type was also recorded (Appendix V).

Shannon-Wiener diversity index and species evenness were calculated for riverine habitats (floodplain, riverine scrub, and open water), which were defined as habitat types that require a body of water to sustain itself, and non-riverine habitats in the dry season using the below equations:

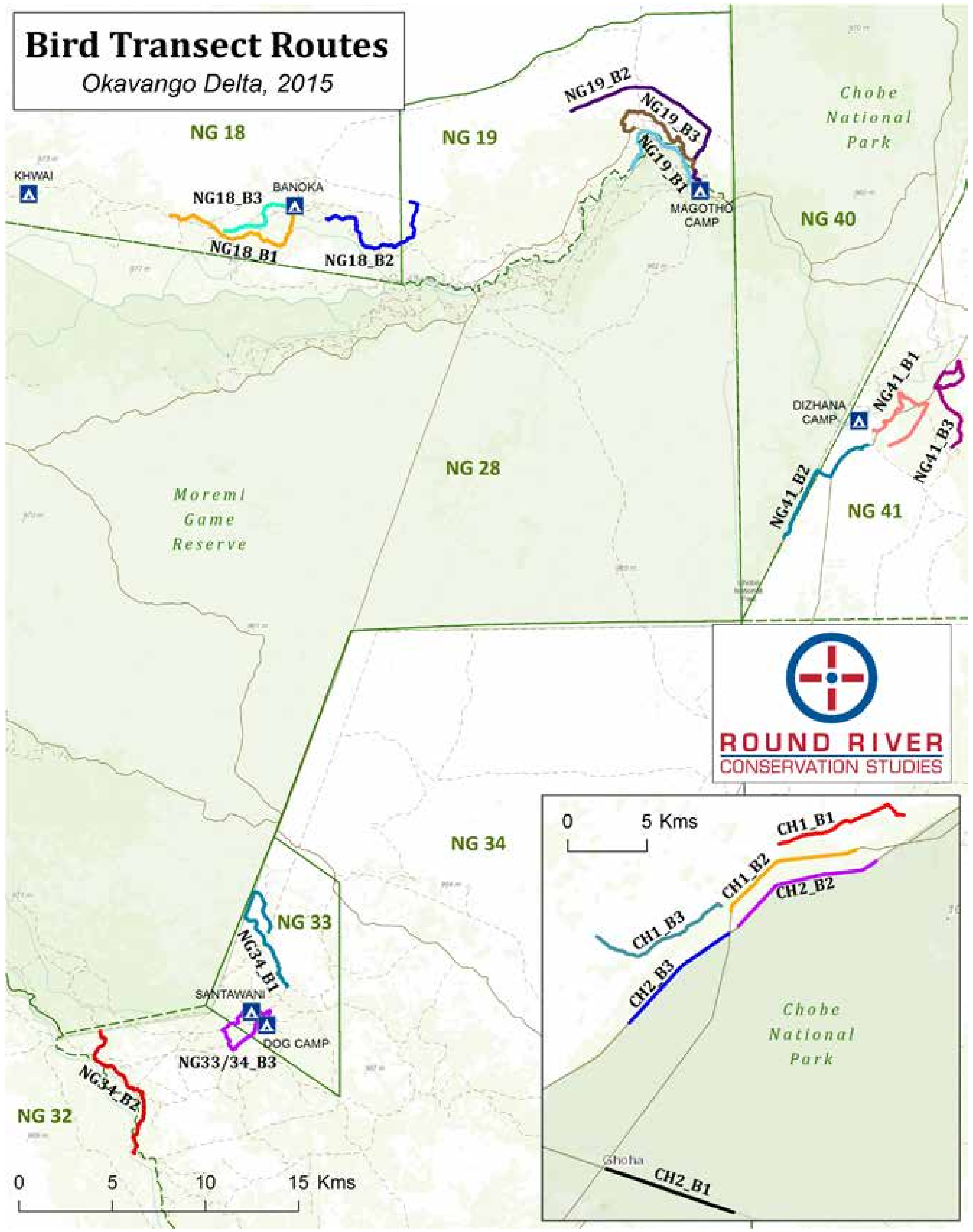

Figure 14. Study area map showing bird survey transects where point counts were completed in 2015.

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$
$$H_{max} = \ln(n)$$

$$Evenness = H'/H_{max}$$

Where:

p_i = Shannon Wiener Diversity Index

p_i = number of individuals of a species i / total number of samples

n = number of species

Birdlife Point Count Bird Surveys

Round River participates in Birdlife Botswana's Bird Population Monitoring (BPM) Program that collects data and information on birds and examines population trends over time (Bird Population Monitoring Programme Instruction Sheet).

BPM requests participants to conduct a point count transect twice a year, in November and February. Point counts contain 11 points 200m apart, covering a distance of approximately 2.0km. They begin between 6-7am and finish before 10am. Weather is recorded based on cloud cover, rain, wind and visibility (Table 22).

Table 22. Weather recorded during bird point count surveys conducted for Birdlife Botswana.

Cloud cover		*Rain*		*Wind*		*Visibility*	
0 - 1/3rd	1	None	1	Calm	1	Good	1
1/3 - 2/3rd	2	Light	2	Light	2	Moderate	2
2/3 - total	3	Heavy	3	Strong	3	Poor	3

At each point count each bird identified by sight of call was recorded within a 5-minute period. Habitat information was recorded based on Birdlife's habitat codes (Appendix V – BPM instruction sheet).

Birdlife Birds of Concern

There are currently 20 bird species listed as Birds of Concern through Birdlife Botswana (*Birdlife Botswana Family of Sites*; Table 23). Round River has opportunistically collected sighting data throughout each of our programs, beginning in the wet season of 2013.

When one of the Birds of Concern was sighted, we recorded the date, time, concession area and approximate location of the sighting, GPS coordinates, and basic behavior (flying, nesting, perching, etc). If possible, age class and sex of the bird was also recorded (Appendix VI – Birds of Concern Data sheet). At the end of each field season we reported this data to Birdlife Botswana. No analysis was conducted on the Bird of Concern data since Birdlife of Botswana has a much larger and robust dataset.

Table 23. Birds of Conservation Concern in Botswana from BirdLife Botswana

Common name	Scientific name
African skimmer	*Rynchops flavirostris*
Bateleur	*Terathiopius ecaudatus*
Black-winged pratincole	*Glareola nordmanni*
Cape vulture	*Gyps coprotheres*
Chestnut-banded plover	*Charadrius pallidus*
European roller	*Coracias garrulus*
Grey crowned heron	*Balearica regulorum*
Hooded vulture	*Necrosyrtes monachus*
Kori bustard	*Ardeotis kori*
Lappet-faced vulture	*Torgos tracheliotus*
Lesser flamingo	*Phoeniconaias minor*
Lesser kestrel	*Falco naumanni*
Maccoa duck	*Oxyura maccoa*
Martial eagle	*Polemaetus bellicosus*
Pallid harrier	*Circus macrourus*
Slaty Egret	*Egretta vinaceigula*
Southern ground hornbill	*Bucorvus leadbeateri*
Wattled crane	*Bugeranus carunculatus*
White-backed vulture	*Gyps africanus*
White-headed vulture	*Trigonoceps occipitalis*

Results

SAREP Point Counts

There were 188 different species of birds and a total of 6,701 individuals identified in the dry and wet seasons of 2015 during point count surveys (Appendix VI). The most common species, both in abundance and distribution, were Cape turtle dove, Red-billed quelea, Burchell's starling and Red-billed spurfowl.

Species evenness and Shannon's Diversity Index are two common ways to represent diversity. Species Evenness is measured between 0 and 1, with 0 representing no evenness and 1 representing perfect evenness. Shannon's Diversity Index takes into consideration species richness and evenness within each area. Assumptions of Shannon's diversity indices are that all individuals are randomly sampled from an independent large population and all of the species are represented in the sample.

The Shannon Diversity Index that we calculated (Table 24) suggests that there is higher species diversity associated with riverine habitats. Species evenness between the two broad habitat types was the same, showing that even though there were different species in each habitat type there was an even spread of bird sightings, and some species were seen more than others.

Table 24. Diversity and evenness indexes for birds found in riverine and non-riverine habitats in 2015.

	Non-Riverine Habitat	Riverine Habitat
Shannon's Diversity Index	2.99	3.25
Species Evenness	0.02	0.02

Birdlife Birds of Concern

RRCS has recorded 943 birds of concern sightings, with 2,225 individuals seen, over 5 seasons (Table 25). The species most sighted was the white-backed vulture, which was also the most common Bird of Concern across the concessions. Bateleur had the second most sightings, due to an incredibly high number of sightings in the wet season of 2015 as well as common in all the areas. Of the twenty Birds of Concern identified by Birdlife Botswana, all but six have been seen throughout all of the research seasons. The unobserved species are the Lesser Flamingo, Pallid Harrier, Grey Crowned Crane, Chestnut-banded Plover, Maccoa Duck, and the Lesser Kestrel. These species are not commonly found in the study region or are seasonal breeders in Northeastern Botswana (BirdLife Botswana Family of Sites 2016).

Discussion and Recommendations

Shannon's Diversity Index and evenness for the SAREP bird point counts were not calculated for the wet season of 2015 due to the difference in methodology for the two seasons. For further bird point counts, we recommend conducting 5 minute counts at each point as opposed to 8 minutes, as the number of new birds counted past the 5-minute mark was minimal. This would also increase the efficiency of the surveys, lead to diminishing the bias so that when the last point count is conducted it is still relatively early in the morning.

Bird surveys help compliment the understanding of biodiversity in the delta and over time will be able to contribute towards reports on biodiversity changes and the state of the environment in Botswana. This includes contributing to develop a Wild Bird Index for Botswana. The SAREP point count survey protocol does not indicate a timing window for the point counts. Therefore, in the future Round River will conduct these point counts in the afternoons while completing herbivore transect in the mornings.

Table 25. Birds of Concern identified opportunistically between 2013-2015, by concession.

	Dry 2013	Dry 2015	Wet 2013	Wet 2014	Wet 2015	Grand Total
Bateleur	**20**	**122**	**53**	**43**	**397**	**635**
CH1	4	13			42	59
CH2	1				14	15
Chobe NP					33	33
NG18	4	26		4	7	41
NG19	7	11	30	14	72	134
NG20					3	3
NG33/34	3	63	15	14	159	254
NG41	1	9	8	11	62	91
Other					5	5
Black-winged pratincole					**100**	**100**
NG41					100	100
Cape vulture		**3**		**1**	**11**	**15**
CH1		3				3
NG19				1	6	7
NG41					5	5
European Roller			**2**		**10**	**12**
NG33/34			2			2
NG41					10	10
Hooded vulture	**5**	**14**			**22**	**41**
NG18	1	1				2
NG19	2				3	5
NG33/34	2	9				11
NG41		4			19	23
Kori bustard	**19**	**64**	**30**	**10**	**44**	**167**
CH1	5	10			1	16
CH2	2					2
Chobe NP		4			12	16
NG19		1		1	1	3
NG33/34	4	3			1	8
NG41	8	44	30	9	28	119
Other		2			1	3
Lappet-faced vulture	**4**	**6**	**0**	**3**	**9**	**22**
CH1	1				2	3
NG18		5				5
NG19	1			2	1	4
NG33/34	2			1		3
NG41		1	0		6	7
Martial eagle	**6**	**19**	**3**	**3**	**13**	**44**
CH1	1	8			1	10
NG18		2		1	1	4

NG19	3				3	6
NG33/34	2	4	3		2	11
NG41		5	0	2	6	13
Secretarybird		**7**				**7**
CH1		1				1
NG41		6				6
Slaty Egret	**7**	**11**	**2**	**2**	**4**	**26**
NG18	1	1	1	1	2	6
NG19		4		1		5
NG33/34		6	1		2	9
NG41	6					6
Southern ground hornbill	**44**	**55**	**17**	**11**	**33**	**160**
CH1	7	11				18
CH2	4				3	7
Chobe NP		26			4	30
NG18	11	1		3	1	16
NG19	21	9	4	8	9	51
NG33/34		5	13		8	26
NG41	1	3	0		8	12
Vulture spp.		**2**			**45**	**47**
NG18		2			32	34
NG19					13	13
Wattled crane	**12**	**2**	**91**	**21**	**31**	**157**
NG18	6	1	1	2	5	15
NG19	4	1	20		18	43
NG33/34			70	7	6	83
NG41	2			12	2	16
White-backed vulture	**230**	**161**	**77**	**42**	**278**	**788**
CH1	30	45			25	100
CH2	23				1	24
Chobe NP					5	5
NG18	19	15	1		38	73
NG19	54	35	33	18	51	191
NG33/34	58	54	28	14	60	214
NG41	44	12	15	10	92	173
Other	2				6	8
White-headed vulture					**4**	**4**
NG19					1	1
NG41					3	3
Grand Total	**347**	**466**	**275**	**136**	**1001**	**2225**

Chapter 3: Community Training and Involvement

An important aspect of implementing a standardized wildlife monitoring protocol in communal concessions is capacity building within the local community. Round River engages trust members within the study area through outreach, meetings, training, and reporting with the goal of eventually having the concessions conduct the surveys without Round River assistance. Thus, all field activities have been conducted in collaboration with community escort guides from Sankuyo Tshwaragano Management Trust, Mababe Zokotsama Community Development Trust, Khwai Zou Development Trust, and the Chobe Enclave Community Trust.

Training Activities

Round River biologists and students are accompanied by community escort guides in each of the concession areas, and the lead biologists provide technical training on wildlife monitoring methodologies, including equipment and computer use.

In each community, Round River provides training to participating community escort guides on the following skills:

- Conducting a game count using standardized distance sampling methodologies
- Using a GPS unit (Garmin eTrex 10 or eTrex 20) to mark and save a waypoint
- Using a digital laser rangefinder (Leupold RX-800i) to measure the distance between the observer and an animal
- Using a compass to take a bearing of an animal's location, relative to the observer
- Recording wildlife sightings on a standardized data sheet during the game counts (written)
- Conducting a bird point count (recording species heard or seen onto a data sheet)
- Recording sightings of Birds of Concern (on a data sheet)
- Setting up, checking, and downloading photos from camera traps
- Conducting spoor surveys
- Entering data onto either an Apple iPad or a lap top computer using the program Microsoft Excel

These technical skills are critical to effective data collection and management, yet are frequently lacking among guides. Round River staff oversees all field activities to ensure standardized protocols are followed. Guides participate in data entry, which is often done in tandem with the Round River students.

Cultural exchange is also a Round River priority. In each concession area, escort guides are invited to camp with the field crew, an experience that provides a platform for cross-cultural exchange between the guides and Round River's students and staff. Round River students are taught basic Setswana during the program so that they may communicate with escort guides in the local language.

Outcomes

In total, 38 community escort guides from three communal trusts have participated in wildlife monitoring activities since the effort began in February 2013 (Table 26, Appendix VII). Of these 38 guides, 15 guides have participated in two field seasons, and 12 have participated in three or more field seasons. In each season, guides usually spend one or two weeks with the field crew conducting wildlife surveys. Guides usually become familiar with protocols and equipment usage within a week, and by the end of training generally demonstrate a moderate level of proficiency. Guides who participate in multiple seasons of the surveys are more proficient than those who participate in fewer. Round River gives certificates of participation to guides at the end of each field season, as a way to formally acknowledge their training.

In the Chobe Enclave, only two community escort guides have participated in the training for two reasons: (1) Round River began working in CH 1 and CH 2 in November 2013 and has only conducted surveys here for a total of three seasons since then (the other concessions have been visited five times since 2013); and (2) Due to financial constraint following the hunting ban that came into effect in 2014., the Chobe Enclave Community Trust has been unable to employ community escort guides since 2014, therefore Round River conducted the surveys without guides in 2015.

Table 26. Numbers of community escort guides in each concession participating in the wildlife surveys and associated training from 2013-2015.

Concession/Trust	# Participating Community Escort Guides	# Guides Participating in 2 field seasons	# Guides Participating in 3 or more field seasons
Sankuyo	7	3	3
Mababe	17	5	5
Khwai	15	7	4
Chobe Enclave	2	0	0

Discussion and Recommendations

Training must continue in order for guides to be proficient in all skills and eventually be able to conduct the surveys without Round River assistance. Each community escort guide should be encouraged to participate in at least two seasons of field activities. Chief escort guides should participate in each season's field activities so that they are capable of helping to train their own guides and to eventually lead the survey efforts.

The end goal of this project is for community escort guides to conduct wildlife monitoring independently, using the standardized methodologies, and to enter data into a shared database. However, a limiting factor for many trusts is funding for their own equipment. It is recommended that trusts allot funding for the purchase of their own monitoring equipment, so that their community escort guides can continue using this equipment throughout the year to hone skills learned and conduct monitoring activities. This will ultimately lead to the trust having enough capacity within its community escort guides to carry out the standardized wildlife surveys on their own. In the meantime, Round River will continue to provide assistance and training to community escort guides, and recognition for skills gained in the form of certificates.

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Appendix I: Herbivore Survey Field Data Sheets and Details

This Appendix provides supplementary information (concession maps, datasheets, habitat definitions, etc) for the field methods used in the wildlife surveys.

Herbivore survey **Month:** **Year:**

Transect: . . . . Date: . . . . Habitat: . . . . Start point GPS: S 19` End point GPS: S 19`

Observers: 1 . . . . 2 . . . . Start point GPS: E 23` End point GPS: E 23`

Driver: . . . . Car: . . . . Start odometer: End odometer:

Weather: . . . . Cloud: . . . . Start time: End time:

Species	Initial count	Adult			Sub-adult			Juvenile			Undet.	Perp. Distance	Angle from N	Odometer reading	Location (South)	Location (East)	Vegetation
		M	F	?	M	F	?	M	F	?							
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Notes:

Date entered: Person entering data:

Figure A- 1. Field data sheet used for recording survey conditions and wildlife data during wildlife transect surveys.

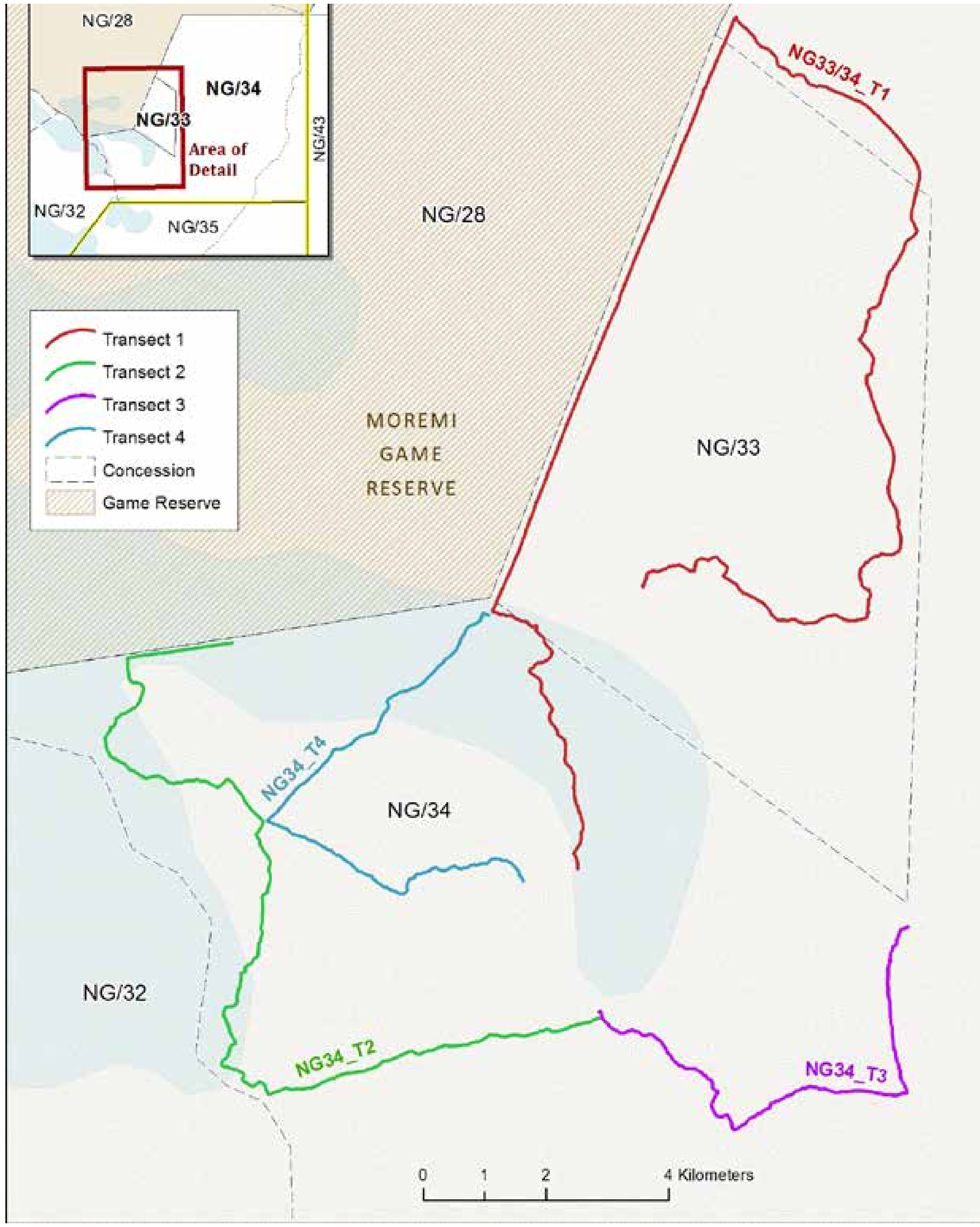


Figure A- 2. Ngamiland 33 and 34 map showing wildlife line transects survey routes used 2013-15.

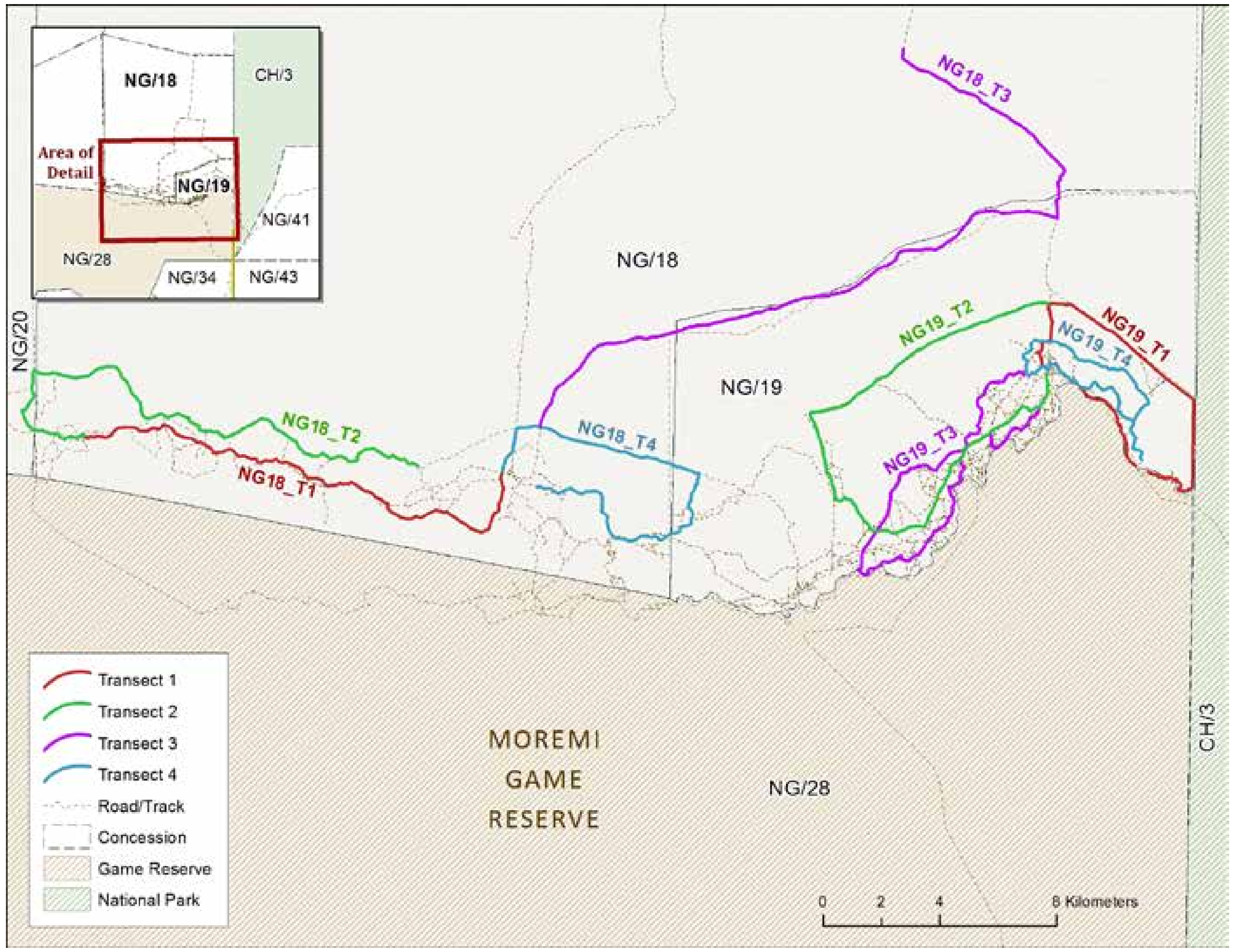


Figure A- 3. Ngamiland 18 and 19 map showing wildlife line transects survey routes used 2013-15.

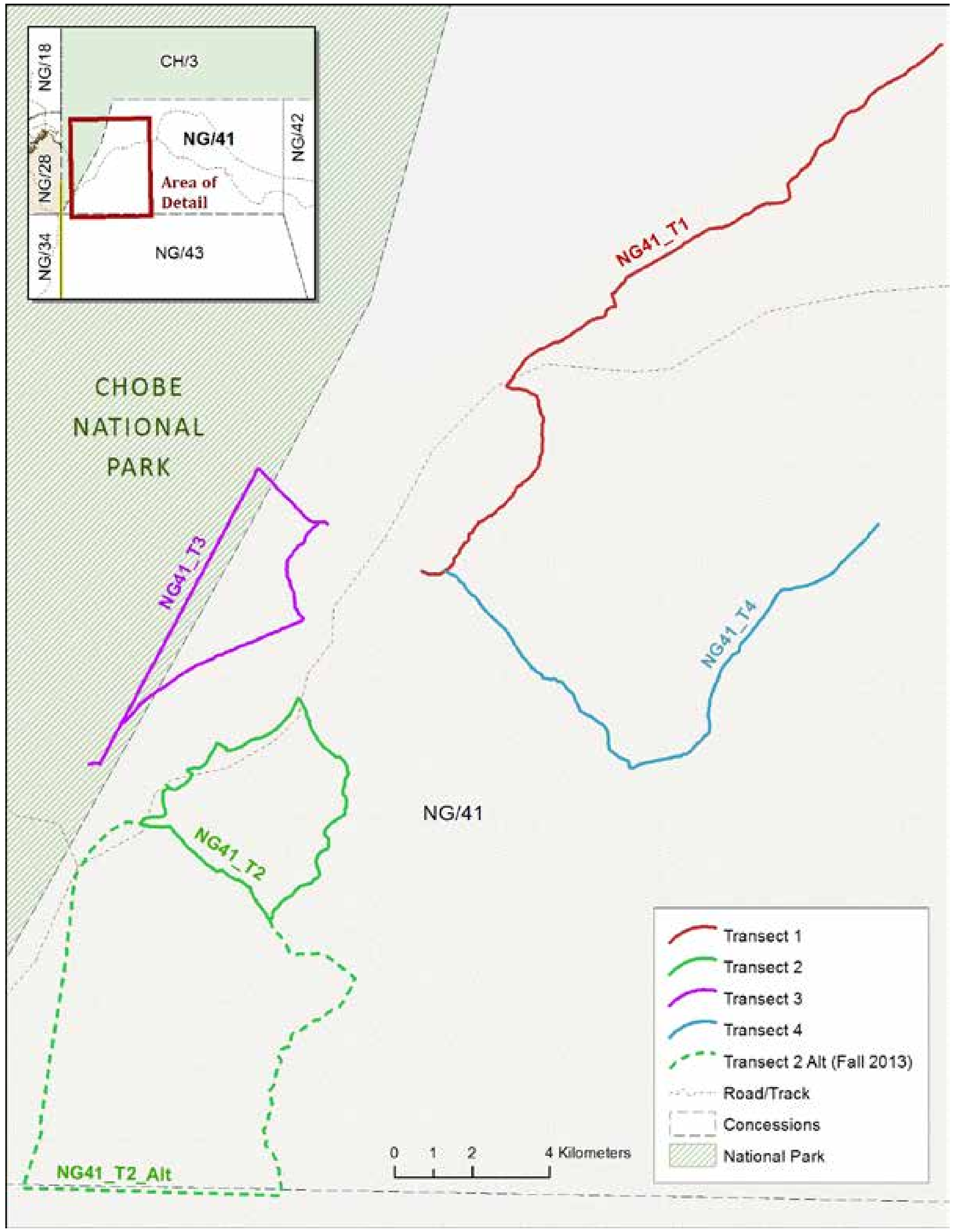


Figure A- 4. Ngamiland 41 map showing wildlife line transects survey routes used 2013-15.

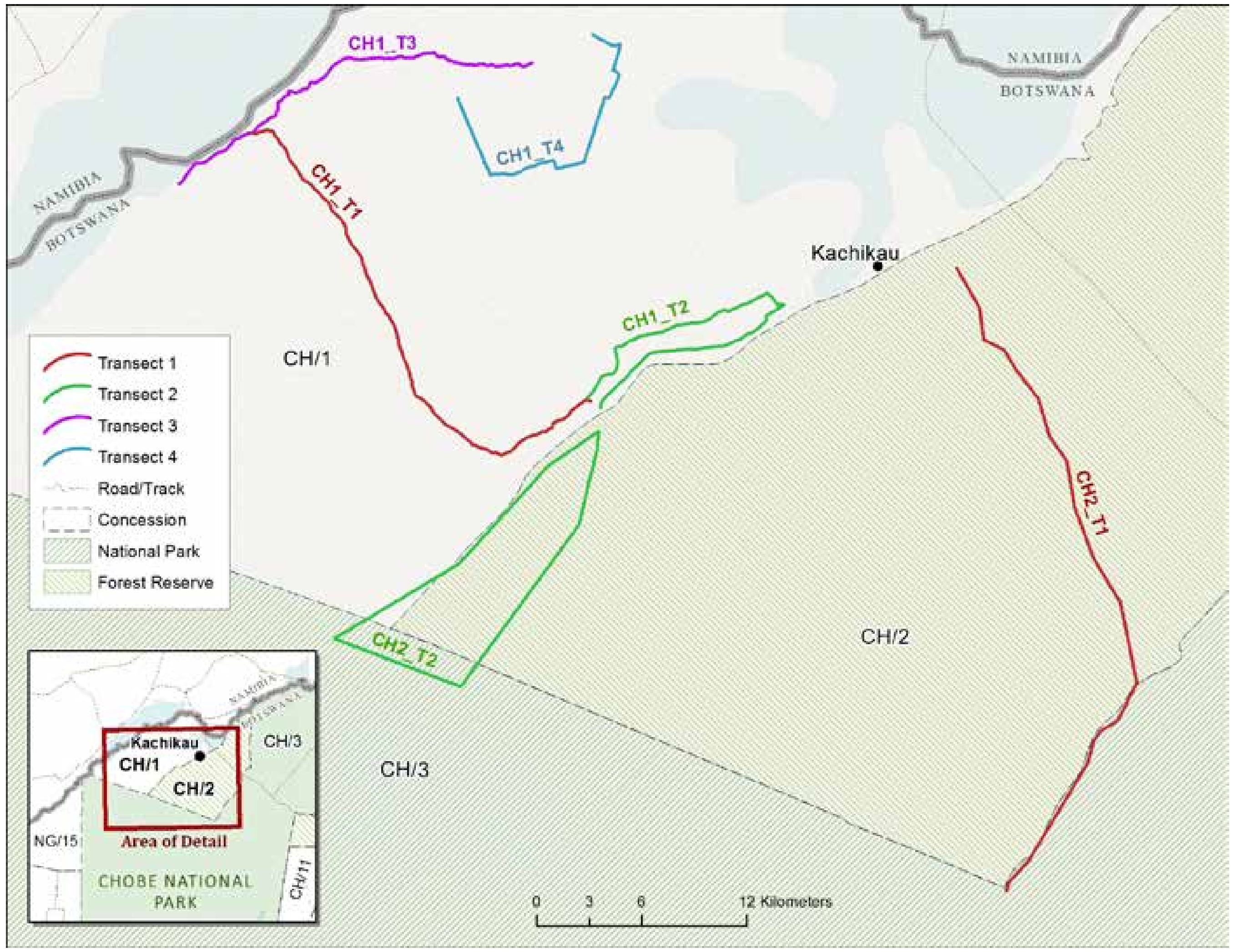


Figure A- 5. Chobe 1 and 2 map showing wildlife line transects survey routes used in 2015.

Table A- 1. Broad habitat types coded in the field at animal observations during surveys were reclassified as open or closed habitat for preliminary assessment of the influence of local habitat sightability on animal detection rates.

Habitat Type	Classification
MMA- Mixed species, Mixed age	Closed
AS – Acacia Scrub	Closed
MW – Mixed Species Woodland	Closed
AL – Appleleaf	Closed
MOSC – Mopane Scrub	Closed
RS – Riverine Scrub	Closed
R – Riparian/Riverine	Closed
MS – Mixed Species Scrub	Closed
SLT – Silver Leaf Terminalia	Closed
AW – Acacia woodland	Open
F - Floodplain	Open
GS - Grassland	Open
OP – Open/Pan	Open

Appendix II: Herbivore Survey Detailed Data Summaries

This appendix provides additional detailed summaries of the species data collected through the 2013-2015 surveys, including group size, demographic details and species counts relative to distance from the transect.

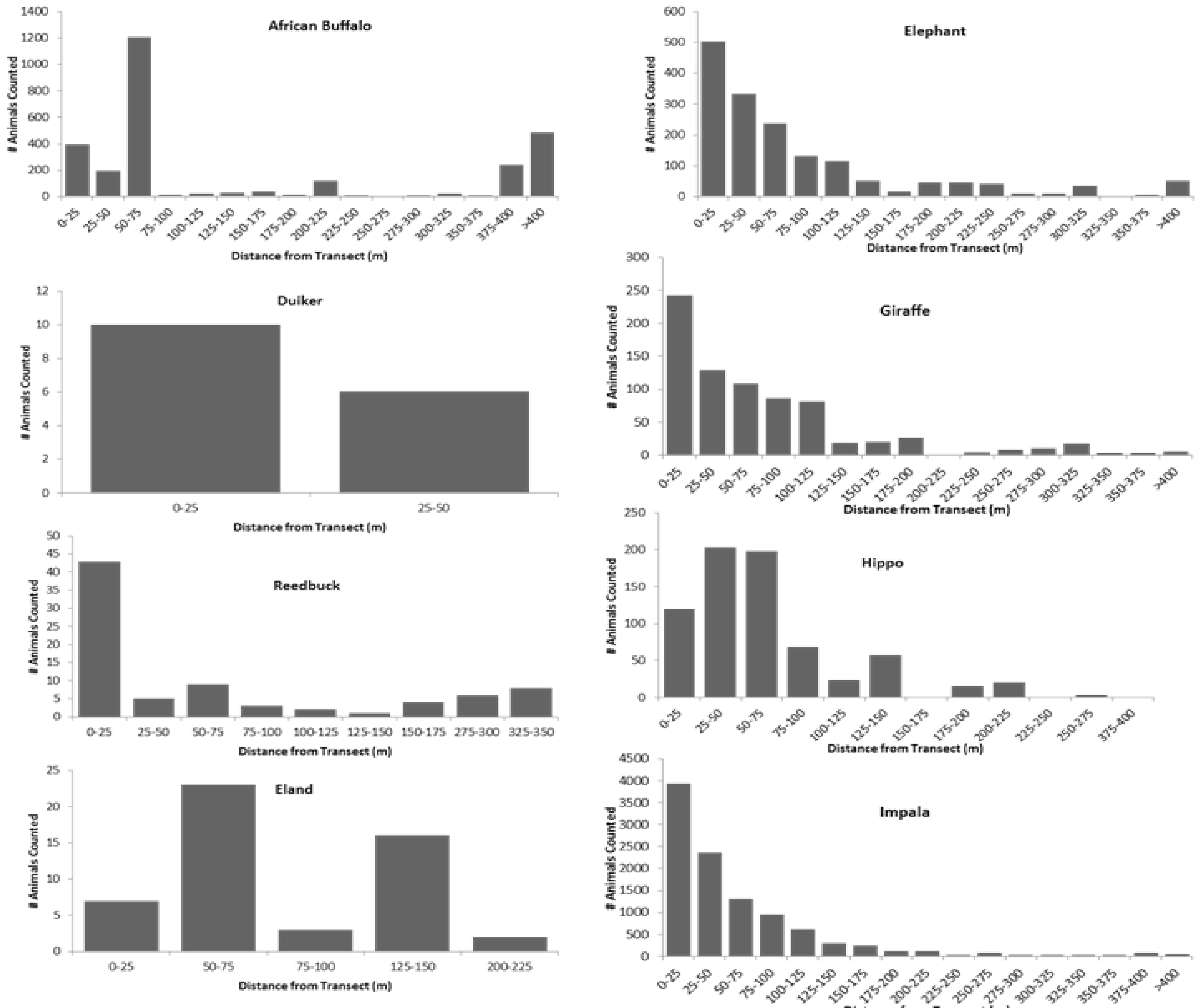
Table A- 2. Number of groups and average size of groups for indicated species across four survey seasons between 2013-2015, pooled across all concessions surveyed.

	Number of Groups				Average size of groups			
	Rep 1	Rep 2	Rep 3	Grand Total	Rep 1	Rep 2	Rep 3	Grand Total
Dry 2013	173	169	146	488	5.36	6.46	6.92	6.71
African buffalo	4	1	2	7	6.75	12.00	4.00	3.73
Elephant	19	14	29	62	2.32	2.29	5.34	2.21
Giraffe	16	25	17	58	1.69	2.56	2.18	9.51
Impala	89	87	73	249	8.01	10.29	10.40	2.96
Kudu	23	21	11	55	2.91	2.95	3.09	1.17
Steenbok	18	19	11	48	1.06	1.32	1.09	2.33
Wildebeest	1	1	1	3	5.00	1.00	1.00	5.33
Zebra	3	1	2	6	8.67	1.00	2.50	6.21
Wet 2014	66	81	61	208	4.06	3.25	5.69	4.22
African buffalo			1	1			1.00	1.00
Elephant	10	16	8	34	2.30	2.00	1.13	1.88
Giraffe	5	10	6	21	1.40	3.10	3.00	2.67
Impala	36	35	34	105	5.22	3.94	6.74	5.29
Kudu	4	4	2	10	2.00	2.50	3.00	2.40
Steenbok		7		7		1.14		1.14
Wildebeest	5	4	7	16	1.80	1.75	8.29	4.63
Zebra	6	5	3	14	5.50	7.40	8.67	6.86
Wet 2015	162	162	180	755	4.44	4.25	3.78	4.14
African buffalo	3	4	3	19	1.67	2.00	1.33	1.70
Elephant	24	21	30	68	1.79	2.05	1.67	1.81
Giraffe	20	24	22	92	1.40	2.71	2.59	2.27
Impala	88	81	89	413	6.68	6.10	5.71	6.16
Kudu	10	14	14	77	2.10	1.57	1.71	1.76
Steenbok	6	7	15	55	1.00	1.00	1.07	1.04
Wildebeest	6	4	3	7	1.17	1.25	1.00	1.15
Zebra	5	7	4	24	4.20	6.29	4.50	5.19
Dry 2015	275	266	214	504	4.31	5.10	4.57	4.66
African buffalo	2	6	11	10	8.50	4.50	4.82	5.11
Elephant	27	24	17	75	2.22	1.92	1.47	1.93
Giraffe	38	33	21	66	2.05	2.09	1.90	2.03
Impala	153	144	116	258	5.79	7.51	6.41	6.56
Kudu	30	27	20	38	3.23	2.96	3.60	3.23
Steenbok	12	23	20	28	1.17	1.00	1.15	1.09
Wildebeest	4		3	13	1.50		1.00	1.29
Zebra	9	9	6	16	3.11	3.44	3.33	3.29

Table A- 3. Summary of demographic data for surveys completed between 2013-2015, including number of adult females and juveniles for African buffalo, elephant, giraffe, impala, kudu, steenbok, wildebeest and zebra presented by concession and season of survey.

	Dry 2013		Wet 2014		Wet 2015		Dry 2015		Total	
	AdF	**Juv**	**AdF**	**Juv**	**AdF**	**Juv**	**AdF**	**Juv**	**AdF**	**Juv**
African Buffalo	**28**	**1**	**4**	**1**	**3**	**0**	**32**	**9**	**67**	**11**
CH1					0	0	0	2	0	2
NG18			0	0			0	0	0	0
NG19	0	0			0	0			0	0
NG33/34	23	1			0	0	0	0	23	1
NG41	5	0	4	1	3	0	32	7	44	8
Elephant	**161**	**102**	**30**	**20**	**45**	**49**	**121**	**70**	**357**	**241**
CH1					0	0	31	18	31	18
CH2					0	0			0	0
NG18	11	14	19	14	1	0	32	4	63	32
NG19	26	9	9	3	17	8	1	1	53	21
NG33/34	96	50	0	1	14	35	14	21	124	107
NG41	28	29	2	2	13	6	43	26	86	63
Giraffe	**51**	**16**	**25**	**4**	**88**	**19**	**98**	**26**	**262**	**65**
CH1					7	0	13	8	20	8
NG18	19	7	9	0	23	7	12	1	63	15
NG19	13	3	0	0	7	0	18	7	38	10
NG33/34	15	6	6	1	35	3	35	7	91	17
NG41	4	0	10	3	16	9	20	3	50	15
Impala	**1572**	**154**	**470**	**122**	**867**	**196**	**1862**	**152**	**4771**	**624**
CH1					0	0	45	0	45	0
CH2					16	0			16	0
NG18	216	20	98	24	92	4	388	31	794	79
NG19	423	36	151	31	376	53	574	32	1524	152
NG33/34	644	83	85	22	326	138	461	85	1516	328
NG41	289	15	136	45	57	1	394	4	876	65
Kudu	**117**	**24**	**12**	**3**	**56**	**16**	**136**	**7**	**321**	**50**
CH1					3	0	11	2	14	2
CH2					2	0			2	0
NG18	38	7	4	1	15	5	54	2	111	15
NG19	15	6	3	1	23	6	38	2	79	15
NG33/34	54	10	5	1	13	5	25	1	97	17
NG41	10	1					8	0	18	1
Steenbok	**28**	**0**	**4**	**0**	**7**	**0**	**31**	**0**	**70**	**0**
CH1					0	0	1	0	1	0
CH2					0	0			0	0
NG18	2	0	1	0	0	0	1	0	4	0
NG19	4	0			0	0	5	0	9	0
NG33/34	16	0	0	0	2	0	10	0	28	0
NG41	6	0	3	0	5	0	14	0	28	0
Wildebeest	**10**	**5**	**30**	**24**	**39**	**18**	**9**	**0**	**88**	**47**
NG18			0	0	0	0	0	0	0	0

	Dry 2013		Wet 2014		Wet 2015		Dry 2015		Total	
	AdF	**Juv**	**AdF**	**Juv**	**AdF**	**Juv**	**AdF**	**Juv**	**AdF**	**Juv**
NG19					0	0	6	0	6	0
NG33/34	0	0			0	0	0	0	0	0
NG41	10	5	30	24	39	18	3	0	82	47
Zebra	**43**	**9**	**69**	**13**	**234**	**77**	**101**	**41**	**447**	**140**
CH1					31	10	35	24	66	34
CH2					4	0			4	0
NG18	24	4	3	1	0	0	18	4	45	9
NG19	19	5	16	6	49	17	32	7	116	35
NG33/34	0	0	0	0	31	3	15	4	46	7
NG41			50	6	119	47	1	2	170	55
Grand Total	**2010**	**311**	**644**	**187**	**1339**	**375**	**2390**	**305**	**6383**	**1178**



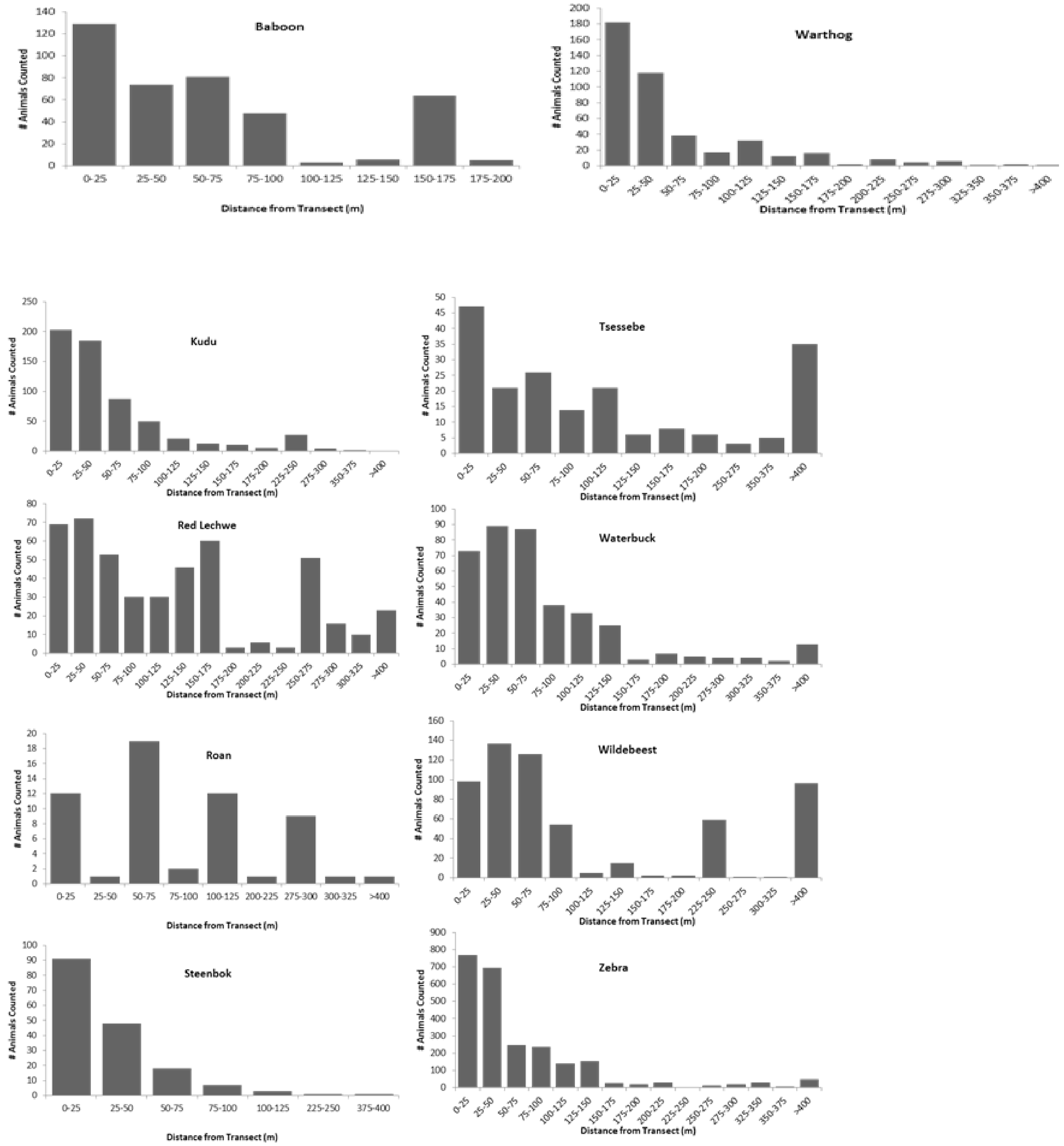


Figure A- 6. Species count distributions relative to distance from transect for all species data pooled over concession surveys conducted between 2013-2015.

Appendix III: Distance Analyses Methodological Details

This appendix provides additional details on the considerations and analyses undertaken to support distance-based density analyses of the 2013-2015 herbivore survey data.

Model Development and Selection

Model selection included evaluating the best fitting key function across recommended options (Table A-4; Buckland et al. 2011). The model with the lowest AICc was selected; if 2 models tied then one model was selected at random. The fit of the selected model to the data was evaluated using Kolmogorov-Smirnov (K-S) tests and 2 Cramer-von Mises tests, visual evaluation of quantile-quantile plots and visual evaluation of the predicted model probabilities against histograms of the data plotted by the distance of observations from the transect (Buckland et al 2001). In the case of the K-S test and the Cramer-von Mises tests, high p-values indicate that it is highly probable that the 2 compared distributions are the same.

All species data were collected as observations of groups or clusters of animals and the number of individuals within each group was recorded. Thus, number of groups and the average group size were key parameters in the modeling and analyses. Group or cluster sizes may be biased with distance (e.g., at larger distances, there may be a higher probability of missing smaller groups). We used regression modeling to test for size bias by distance in the detection function, and if there was significant bias (slope >0.15), we used the regression to adjust expected cluster size.

Data were truncated to remove the most distant observations as these may represent outliers or have higher uncertainty than observations closer to the transect. When data were broken into intervals (e.g., 0-25m, 25-50m) the boundary of the most distant interval became the truncation (often 300m). When exact distances were used in the analyses, we truncated to remove the farthest 5% of observations.

We did not pool cluster size estimates or encounter rates (#observations/km) across concessions. These were based on concession-level data, as we expect these to be the primary determinants of concession-level species densities. Thus, population density estimates for each concession used the global detection function built upon the identified larger data set (e.g., dry season pooled) and concession-specific encounter rates and effort. Population density estimates calculated for individual concessions have high uncertainty due to the smaller samples sizes within any conservancy.

Table A- 4. Models evaluated for potential use to model the detection function for each species, limiting the potential adjustment factors to 5 or less.

Model	Series Expansion
Uniform	Cosine
Half-Normal	Cosine
Half-Normal	Hermite polynomial
Hazard Rate	Simple polynomial

Exploring distance distributions and sources of variation in count data

Pooling of data will increase our ability to appropriately use distance analyses by effectively increasing the sample size used to generate the PDF model, which has high sample size requirements. These assessments were limited to those species with sufficient sample size to offer the possibility of distance-based analyses.

<u>Influence of Sample Size.</u> Distance analyses and particularly the development of robust probabilities of detection functions have high sample size requirements. To recommend a minimum sample size for distance analyses, we conducted a sensitivity analyses of the PDF to sample size using the dry season impala data - which is the largest seasonal data set (n=800 observations within 300m of the transect) and notably larger than data collected on other species thus providing a reasonable baseline test data set. We pooled impala dry season data, assigned each observation a random number between 0-1, sorted on this random number to allow us to randomly subsample the dataset at selected sample sizes. We generated 7 PDF models for samples sizes ranging from 800 to 100 observations. This comparison suggests that potentially important changes in predicted probability of detection curves is apparent at sample sizes of 300 or less observations (Figure A- 7). The absolute difference between the PDF generate with n=800 and the PDFs generated at smaller sample sizes (Figure A- 8) also suggests that at sample sizes of <=300, probability of detection predictions can be close to 20% higher than the base model at n=800. Minimizing the difference to less than 10% would suggest sample size requirements closer to 400 observations or more. The acceptable level of potential error in the detection probability is unclear but a sensitivity analyses suggests that the relative change between the base PDF (n=800) and subsamples jumps between n=300 and n=400. Part of the change is due to an AIC selection of model functions that shifts from a hazard rate function to a half-normal function at the break point. Forcing a hazard rate function model regardless of sample size suggests similar sample size biases.

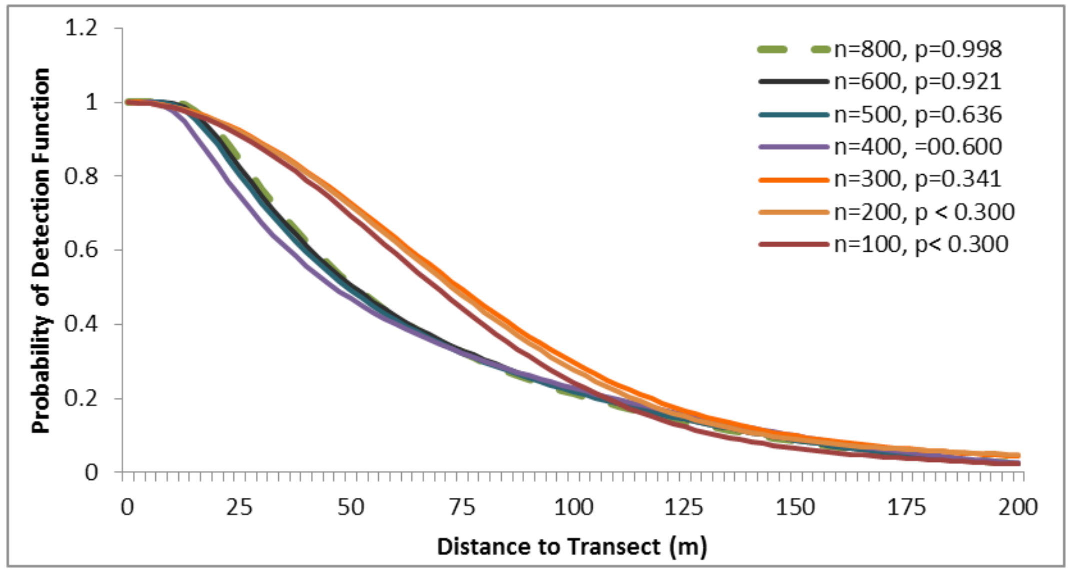


Figure A- 7. Probability of detection models developed for subsampled impala data with subsamples ranging from 100 to 800 to evaluate the changes in the fit of the model to the data; p-values provide probability that the model and the data are generated from the same population so higher p-values are desired as a metric of good fit between the data and the model.

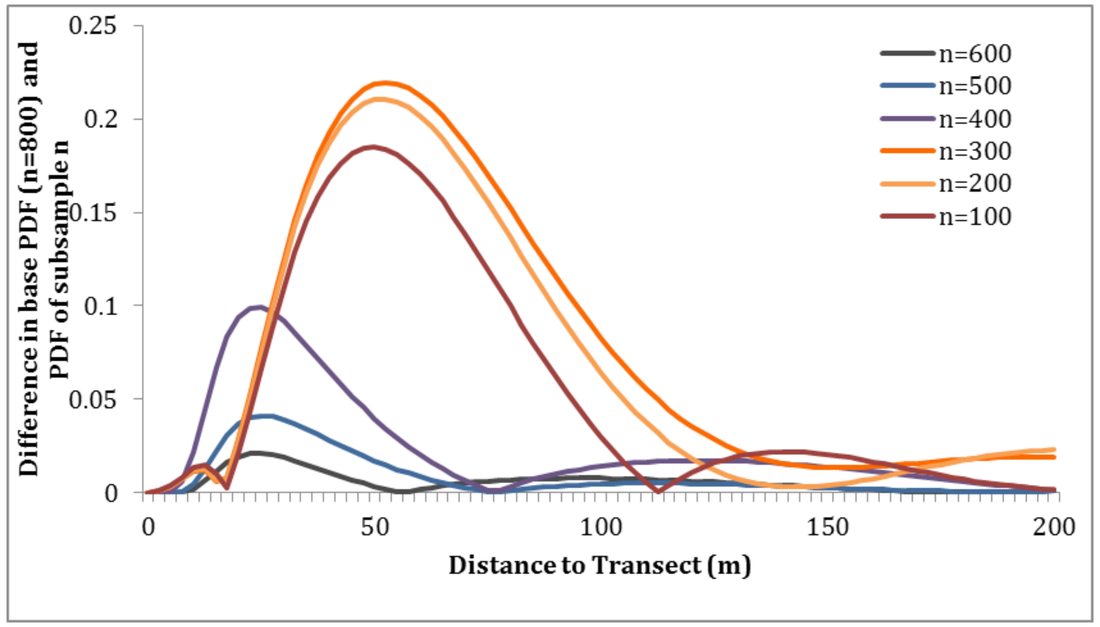


Figure A- 8. The absolute differences in the predicted probability of detection between the best fit model (n=800) and other models generated from smaller subsamples of the data.

Sample Size and Estimated Density. The influence of sample size is clear in the development of the PDF. We evaluated if this then translates into important differences in the estimated density, again using the dry season impala data as a test set. For this assessment, we pooled data across the Ngamiland concessions for the dry season surveys and incrementally removed transect replicates to effectively reduce the sampling effort and therefore the number of observations. We see that regardless of sample size, the 95% confidence intervals are quite broad around the estimated density and this remains true across all sample sizes. The primary component of the variation in all instances is variation in the encounter rates (i.e., # observations/km of transect), which we expect to vary in time and space. Still, our ability to statistically 'prove' a decline in a species density even with excellent sample sizes is limited given the confidence intervals observed. However, we expect with reasonable sample sizes, such analyses should provide insights into trends in density, if the threshold for identifying trend is not a statistically significant threshold. In evaluating the influence of sample size on density estimates, it is notable that the estimated density drops when sample size drops below 250 observations, similar to the sample size guidelines based on PDF fit to the survey data. The chi-square statistic for PDF fit to the data drops from 0.94 at n = 650 to 0.10 at n=143, similar to our prior evaluation of sample size influence on fitting a PDF to the underlying data.

Influence of Local Habitat. Based on a classification of habitat at observed animals that was collected during field surveys, we created a 2-class vegetation grouping that indicated if the observed animal group was in generally open habitat or closed habitats.

Table A-1). The vegetation classification appears useful in further understanding the variability in the probability of detection for each season. As might be expected, in open habitats, the probability of detection remains higher at further distance compared to the probability of detection when the animal is in locally closed habitats. In fact, the most pronounced differences between PDF functions are seasons followed by broad vegetation structure at the sighting (Figure A- 10). Where possible, based on sample size, it would be ideal to include the local habitat structure as a co-variant in the distance analyses.

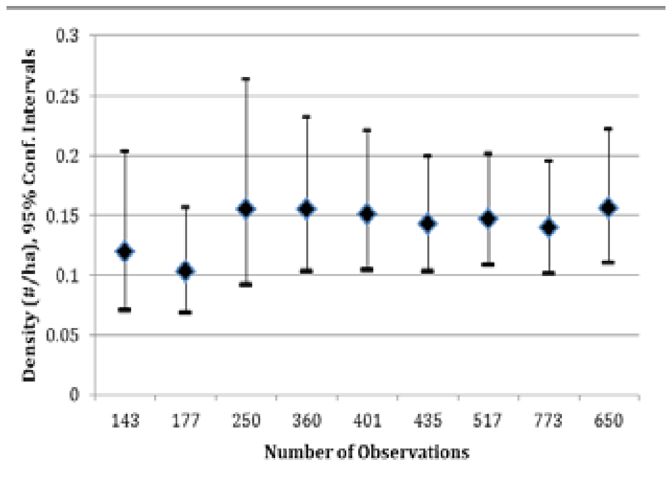


Figure A- 9. Estimated densities of impala generated with indicated random sample sizes, shown with 95% confidence intervals

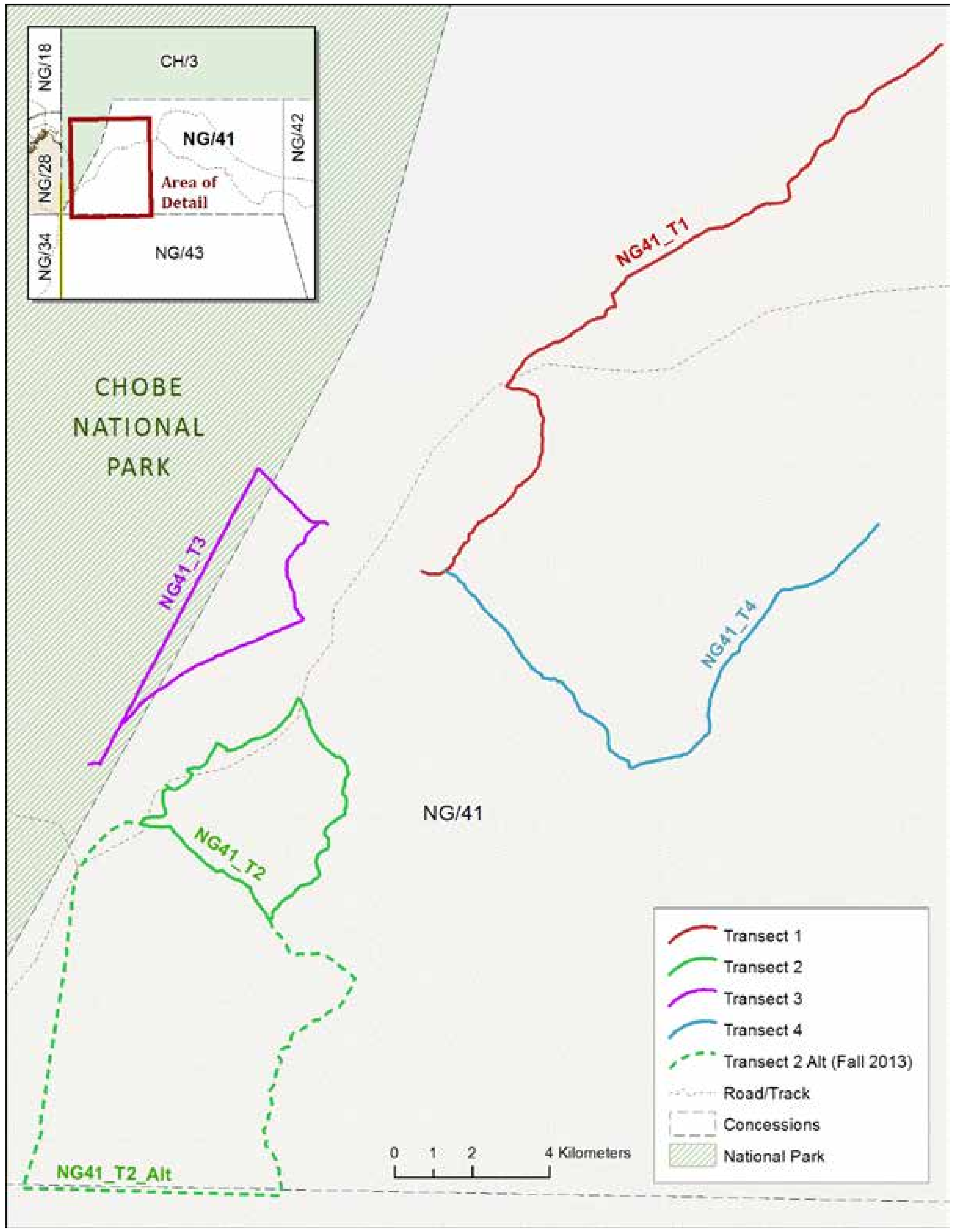


Figure A- 4. Ngamiland 41 map showing wildlife line transects survey routes used 2013-15.

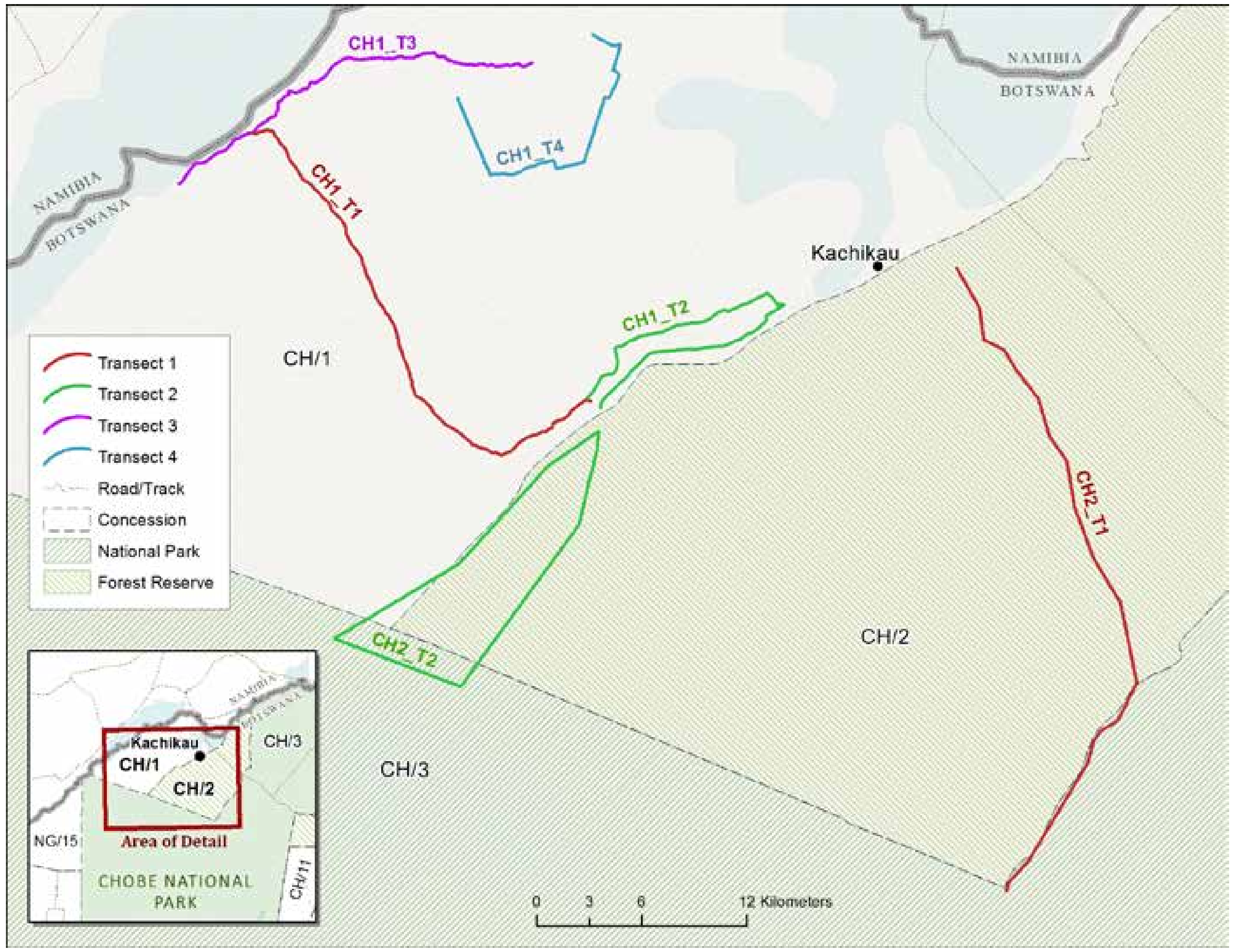


Figure A- 5. Chobe 1 and 2 map showing wildlife line transects survey routes used in 2015.

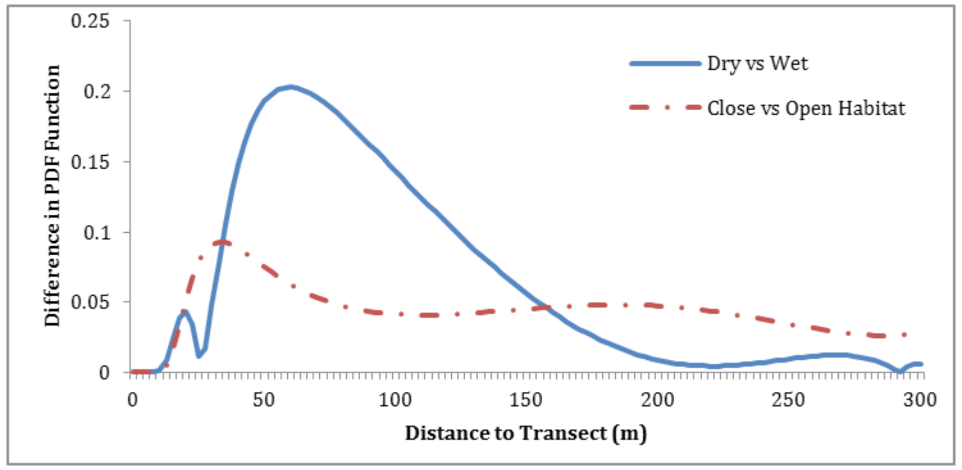


Figure A- 10. Absolute difference in the probability of detection for impala between dry and wet seasons and between closed and open habitat.

Distance Modeling Parameters and Results Details

Basic density results are provided in the body of the report. Here, we provide additional parameter estimates developed for the distance analyses (Table A- 5). The definitions for the columns are:

k = Number of Transects (in which replicates are pooled)
L = Total transect length
N = Number of groups
S = Average cluster/herd size
E(S) = Expected cluster/herd size corrected for any distance bias using regression if slope is significant at p<0.15
Ds = Density of clusters

Table A- 5. Distance model parameters and estimates for species during seasons and in concessions for which 2013-2015 survey data were sufficient to develop model; see text for parameter definitions.

Species	Concession	Seas-Year	k	L	n	S	E(S)	Ds	n/L
Elephant	NG 18	Dry 2013	2	120	9	5.67	5.67	0.55	0.07
Elephant	NG 18	Wet 2014	2	113	11	6.55	6.55	0.72	0.10
Elephant	NG 18	Wet 2015	3	174	2	3.00	3.00	0.08	0.01
Elephant	NG 18	Dry 2015	4	269	19	6.00	6.00	0.52	0.07
Elephant	NG 19	Dry 2013	4	230	22	2.82	2.82	0.71	0.10
Elephant	NG 19	Wet 2014	2	115	9	3.22	3.22	0.58	0.08
Elephant	NG 19	Wet 2015	4	234	26	3.54	3.54	0.82	0.11
Elephant	NG 19	Dry 2015	4	239	15	2.73	2.73	0.46	0.06
Elephant	NG 33-34	Dry 2013	4	243	29	6.86	6.86	0.88	0.12
Elephant	NG 33-34	Wet 2014	2	148	5	1.80	1.80	0.25	0.03
Elephant	NG 33-34	Wet 2015	4	240	21	4.19	4.19	0.65	0.09
Elephant	NG 33-34	Dry 2015	4	233	31	4.97	4.97	0.98	0.13
Elephant	NG 41	Dry 2013	4	264	28	4.14	4.14	0.78	0.11
Elephant	NG 41	Wet 2014	2	119	16	1.94	1.94	0.99	0.13
Elephant	NG 41	Wet 2015	4	253	23	2.61	0.93	0.67	0.09
Elephant	NG 41	Dry 2015	4	235	38	5.66	5.66	1.20	0.16
Giraffe	NG 18	Dry 2013	2	120	17	3.18	3.18	0.99	0.14
Giraffe	NG 18	Wet 2014	2	113	5	2.80	2.80	0.22	0.04
Giraffe	NG 18	Wet 2015	3	174	13	4.15	4.15	0.38	0.07
Giraffe	NG 18	Dry 2015	4	269	16	2.00	2.00	0.42	0.06
Giraffe	NG 19	Dry 2013	4	230	14	2.00	1.30	0.43	0.06
Giraffe	NG 19	Wet 2014	2	115	1	2.00	2.00	0.04	0.01
Giraffe	NG 19	Wet 2015	4	234	7	1.86	1.86	0.15	0.03
Giraffe	NG 19	Dry 2015	4	239	12	3.00	3.00	0.35	0.05
Giraffe	NG 33-34	Dry 2013	4	243	27	1.89	1.89	0.78	0.11
Giraffe	NG 33-34	Wet 2014	2	148	12	2.17	2.17	0.41	0.08
Giraffe	NG 33-34	Wet 2015	4	240	43	2.14	2.14	0.90	0.18
Giraffe	NG 33-34	Dry 2015	4	233	45	2.16	2.16	1.35	0.19

Species	Concession	Seas-Year	k	L	n	S	E(S)	Ds	n/L
Giraffe	NG 41	Dry 2013	4	264	8	2.38	0.16	0.21	0.03
Giraffe	NG 41	Wet 2014	2	119	3	5.67	5.67	0.13	0.03
Giraffe	NG 41	Wet 2015	4	254	12	5.08	5.08	0.24	0.05
Giraffe	NG 41	Dry 2015	4	235	23	2.65	2.65	0.69	0.10
Impala	NG 18	Dry 2013	2	120	39	8.05	8.05	2.40	0.32
Impala	NG 18	Wet 2014	2	113	36	6.97	1.99	3.29	0.32
Impala	NG 18	Wet 2015	3	174	77	6.19	4.99	4.58	0.44
Impala	NG 18	Dry 2015	4	269	79	7.82	7.82	2.17	0.29
Impala	NG 19	Dry 2013	4	230	56	15.88	15.88	1.80	0.24
Impala	NG 19	Wet 2014	2	115	20	11.15	11.15	1.80	0.17
Impala	NG 19	Wet 2015	4	234	95	9.07	9.07	4.20	0.41
Impala	NG 19	Dry 2015	4	239	108	8.93	8.93	3.35	0.45
Impala	NG 33-34	Dry 2013	4	243	142	8.90	8.90	4.32	0.58
Impala	NG 33-34	Wet 2014	2	148	44	9.07	2.82	3.07	0.30
Impala	NG 33-34	Wet 2015	4	240	86	9.50	9.50	3.71	0.36
Impala	NG 33-34	Dry 2015	4	233	226	4.58	4.58	7.15	0.97
Impala	NG 41	Dry 2013	4	264	40	13.18	11.17	1.12	0.15
Impala	NG 41	Wet 2014	2	119	12	15.08	--	1.04	0.10
Impala	NG 41	Wet 2015	4	253	33	11.09	11.09	1.35	0.13
Impala	NG 41	Dry 2015	4	235	83	10.47	8.85	2.61	0.35
Kudu	NG 18	Dry 2013	2	120	13	3.62	3.62	0.76	0.11
Kudu	NG 18	Dry 2015	4	269	19	3.58	2.18	0.50	0.07
Kudu	NG 19	Dry 2013	4	230	15	2.20	2.20	0.46	0.07
Kudu	NG 19	Dry 2015	4	239	22	3.18	3.18	0.65	0.09
Kudu	NG 33-34	Dry 2013	4	243	23	3.48	3.48	0.67	0.09
Kudu	NG 33-34	Dry 2015	4	233	16	3.25	2.72	0.48	0.07
Kudu	NG 41	Dry 2013	4	264	7	3.29	3.29	0.19	0.03
Kudu	NG 41	Dry 2015	4	235	13	3.15	3.15	0.39	0.06
Steenbok	NG 18	Dry 2013	2	120	3	1.33	1.33	0.39	0.02
Steenbok	NG 18	Dry 2015	4	269	7	1.29	1.29	0.40	0.03
Steenbok	NG 19	Dry 2013	4	230	8	1.00	1.00	0.54	0.03
Steenbok	NG 19	Dry 2015	4	239	7	1.43	1.43	0.46	0.03
Steenbok	NG 33-34	Dry 2013	4	243	28	1.18	1.18	1.79	0.12
Steenbok	NG 33-34	Dry 2015	4	233	18	1.11	1.11	1.20	0.08
Steenbok	NG 41	Dry 2013	4	264	14	1.14	1.14	0.82	0.05
Steenbok	NG 41	Dry 2015	4	235	27	1.07	1.07	1.79	0.11
Warthog	NG 18	Dry 2013	2	120	6	3.67	3.67	0.39	0.05
Warthog	NG 18	Dry 2015	4	269	8	2.25	2.25	0.23	0.03
Warthog	NG 19	Dry 2013	4	230	14	2.00	2.00	0.48	0.06
Warthog	NG 19	Dry 2015	4	239	19	2.47	2.47	0.63	0.08
Warthog	NG 33-34	Dry 2013	4	243	20	1.85	1.85	0.65	0.08
Warthog	NG 33-34	Dry 2015	4	233	17	2.00	2.00	0.57	0.07

Species	Concession	Seas-Year	k	L	n	S	E(S)	Ds	n/L
Warthog	NG 41	Dry 2013	4	264	13	1.69	1.69	0.39	0.05
Warthog	NG 41	Dry 2015	4	235	16	2.50	2.50	0.53	0.07
Zebra	NG 18	Dry 2013	2	120	7	8.14	8.14	0.36	0.06
Zebra	NG 18	Wet 2014	2	113	3	3.67	3.67	0.16	0.03
Zebra	NG 18	Wet 2015	3	174	3	3.33	3.33	0.11	0.02
Zebra	NG 18	Dry 2015	4	269	10	4.80	4.80	0.23	0.04
Zebra	NG 19	Dry 2013	4	230	5	9.60	9.60	0.13	0.02
Zebra	NG 19	Wet 2014	2	115	6	8.00	8.00	0.32	0.05
Zebra	NG 19	Wet 2015	4	234	21	8.19	8.19	0.55	0.09
Zebra	NG 19	Dry 2015	4	239	18	6.89	6.89	0.46	0.08
Zebra	NG 33-34	Dry 2013	4	243	3	2.00	2.00	0.08	0.01
Zebra	NG 33-34	Wet 2014	2	148	2	2.00	2.00	0.08	0.01
Zebra	NG 33-34	Wet 2015	4	240	12	7.67	7.67	0.31	0.05
Zebra	NG 33-34	Dry 2015	4	233	12	6.17	6.17	0.31	0.05
Zebra	NG 41	Dry 2013	4	264	1	7.00	7.00	0.02	0.00
Zebra	NG 41	Wet 2014	2	119	8	11.00	8.37	0.41	0.07
Zebra	NG 41	Wet 2015	4	254	16	35.56	35.56	0.39	0.06
Zebra	NG 41	Dry 2015	4	235	6	6.00	--	0.16	0.03

Appendix IV: Strip Width Results

This appendix provides addition detailed summaries of data used to calculate strip width densities for herbivores. Table A- 6 provides a summary of the total sample size (counts) of animals that fell within the 100m strip and were used to calculate estimated densities. Table A- 7 includes the calculated densities along with variance statistics for all species. We strongly urge that only densities with CV ≤ 0.50 be considered but include all estimates for completeness.

Table A- 6. Effort, total animals counted (n), and animals counted within 50m on each side of the transect (100m strip) for each of four seasonal surveys and each concession surveyed. Also shown is the percent of animals seen within 50m of the transect.

	Dry 2013				Wet 2014				Wet 2015				Dry 2015			
	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total
AFRICAN BUFFALO																
CH1									94.1	8	5	63	83.0	140	140	100
NG18					19.7	1	1	100					194.0	35	3	9
NG19	24.5	13	13	100					19.6	2			49.7	37	33	89
NG33-34	136.7	67							63.3	8	6	75	175.2	111	9	8
NG41	127.3	321	303	94	43.4	1207	7	1	106.2	8	5	63	260.0	856	70	8
BABOON																
CH1									27.5	1	1	100	54.1	6	2	33
NG18	38.2	2	2	100	55.9	43	43	100	39.2	20	6	30	99.9	33	11	33
NG19	36.5	14	2	14					113.5	62	59	95	24.8	20		
NG33-34	39.0	16	11	69					89.2	33	32	97	109.2	22	12	55
NG41	41.3	1	1	100									143.3	138	22	16
COMMON DUIKER																
CH1													84.6	5	5	100
CH2									192.0	5	5	100				
NG18													27.5	1	1	100
NG33-34	9.8	1	1	100												
NG41	83.9	4	4	100												
COMMON REEDBUCK																
NG18	82.0	9	8	89					197.0	16	14	88	148.8	20	12	60
NG19	11.6	2							115.1	12	8	67	17.0	3		
NG33-34									41.2	6	6	100				
NG41	44.7	14														
ELAND																
CH1													125.7	37	7	19
NG41					20.5	11			24.0	3						
ELEPHANT																
CH1									31.2	2			551.3	121	76	63
CH2									120.0	5	5	100				
NG18	176.7	51	36	71	209.0	72	60	83	38.0	6	5	83	464.2	116	65	56
NG19	535.4	87	47	54	170.5	29	23	79	558.0	96	86	90	345.2	42	19	45
NG33-34	788.6	199	90	45	148.6	9	7	78	609.6	101	62	61	890.0	160	73	46
NG41	915.4	162	32	20	329.8	32	16	50	551.7	67	23	34	930.7	278	112	40

	Dry 2013				Wet 2014				Wet 2015				Dry 2015			
	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total
GIRAFFE																
CH1									118.8	21	12	57	488.7	50	14	28
NG18	355.3	61	32	52	95.7	14	13	93	377.4	79	44	56	379.7	35	10	29
NG19	304.5	30	18	60	20.2	2			125.6	13	7	54	329.3	46	17	37
NG33-34	664.9	54	31	57	412.9	28	11	39	1351.1	98	55	56	1265.7	101	53	52
NG41	186.4	19	4	21	62.3	17	16	94	259.7	65	27	42	494.2	68	39	57
HIPPO																
NG18	123.7	13	9	69	19.7	1			120.0	26	24	92	203.2	46	37	80
NG19	381.2	113	25	22	58.0	14	10	71	449.2	168	93	55	585.8	115	39	34
NG33-34	188.1	14	5	36	15.2	2	2	100	130.4	27	5	19	38.9	7		
NG41	102.9	11	6	55	93.3	28	17	61	214.1	102	45	44	228.8	33	6	18
IMPALA																
CH1									220.2	47	41	87	743.0	128	50	39
CH2									40.0	17	17	100				
NG18	783.6	314	157	50	672.4	251	181	72	1584.4	545	357	66	1721.4	662	444	67
NG19	1188.2	931	610	66	403.4	224	157	70	2031.4	986	666	68	2102.3	1100	544	49
NG33-34	3741.2	1267	870	69	1302.3	172	98	57	2880.1	858	649	76	7018.1	1037	691	67
NG41	980.1	567	265	47	262.2	211	16	8	659.2	366	273	75	1771.9	975	390	40
KUDU																
CH1									90.6	6	6	100	287.2	28	17	61
CH2									80.0	2	1	50				
NG18	284.4	50	24	48	73.3	8	7	88	296.0	27	18	67	462.7	82	41	50
NG19	314.1	38	28	74	57.7	8	4	50	436.5	55	34	62	418.0	70	49	70
NG33-34	456.7	80	67	84	99.9	11	6	55	233.4	29	23	79	371.5	52	33	63
NG41	172.6	25	14	56									253.8	41	21	51
OSTRICH																
CH1									130.5	6	4	67	295.9	21	11	52
NG18									20.3	2	2	100	21.8	11	11	100
NG19									50.0	12	12	100				
NG33-34	88.7	9	6	67	34.4	1			24.7	4						
NG41	41.3	2			126.4	33	26	79	18.9	2	2	100	19.8	11	11	100
RED LECHWE																
NG18	21.3	1							143.2	44	43	98	270.0	93	7	8
NG19	161.6	38	3	8	55.9	21	21	100	160.0	33	16	48	206.7	40	23	58
NG33-34	117.4	35							58.3	46			187.8	125	28	22
ROAN																
CH1													21.2	1	1	100
NG18	21.0	6											99.8	19	6	32
NG19	25.1	2	2	100												
NG33-34													18.5	3	3	100
NG41	41.3	1											167.3	26	1	4

	Dry 2013				Wet 2014				Wet 2015				Dry 2015			
	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total	Total km	n	100m n	% of Total
SABLE																
NG18	20.0	1	1	100												
NG19	25.1	2			18.7	1										
STEENBOK																
CH1									67.6	2	2	100	83.5	3	2	67
CH2									202.2	6	6	100				
NG18	59.7	4	2	50	38.2	3	3	100	19.0	1	1	100	187.5	10	8	80
NG19	198.8	8	6	75					19.0	1	1	100	155.7	10	10	100
NG33-34	753.6	34	26	76	71.0	2	2	100	148.6	6	6	100	450.4	20	18	90
NG41	398.8	16	12	75	54.8	3	2	67	330.9	16	12	75	533.9	29	25	86
TSESSEBE																
NG18	80.5	13	2	15					20.0	5	5	100	59.9	12	7	58
NG19	39.7	10							39.0	2	1	50	84.5	13	4	31
NG33-34	76.1	9	6	67	103.3	13	13	100	50.2	3			255.1	23	7	30
NG41	45.6	14	9	64	20.5	11	11	100	88.1	5	2	40	110.4	59	1	2
WARTHOG																
CH1									27.5	3	3	100	549.4	37	22	59
CH2									40.0	4	4	100				
NG18	121.3	22	15	68					59.5	12	5	42	205.8	19	14	74
NG19	315.5	31	16	52	95.0	15	12	80	149.2	28	17	61	398.8	49	28	57
NG33-34	458.3	37	32	86	29.9	2	2	100	73.5	5	5	100	360.0	34	21	62
NG41	324.2	23	14	61	188.9	26	22	85	301.4	40	36	90	459.0	52	32	62
WATERBUCK																
NG18	105.8	33	20	61					78.7	10	5	50	225.0	71	35	49
NG19	211.8	39	14	36					570.2	84	43	51	454.3	79	30	38
NG41	104.7	14			59.4	12	11	92	94.9	22	5	23	254.5	29	1	3
WILDEBEEST																
CH1													30.6	18	18	100
NG18					17.5	1	1	100	20.0	1	1	100	20.3	1	1	100
NG19	20.0	3	3	100					32.1	2	1	50	32.1	49	49	100
NG33-34	90.2	8	6	75					51.0	2			158.1	5		
NG41	178.9	111	14	13	366.2	169	113	67	265.9	152	38	25	264.5	98	13	13
ZEBRA																
CH1									422.5	140	69	49	1148.5	908	474	52
CH2									40.0	4	4	100				
NG18	144.0	57			55.9	11	3	27	60.9	10	8	80	224.0	48	34	71
NG19	103.9	48	8	17	112.0	48	22	46	418.4	187	96	51	372.6	124	61	49
NG33-34	65.0	6	4	67	50.2	4	4	100	372.8	104	61	59	331.4	74	62	84
NG41	21.6	7	7	100	172.7	88	58	66	372.7	569	520	91	119.9	36	1	3

All strip width density calculations are provided, regardless of the CV. We warn that density estimates with high CVs have high variance and low confidence. The total number of animals observed (N) is provided; df would be N-1.

Table A- 7. Strip width density results for all herbivore species encountered, calculated for each season and concession for which encounters were recorded.

	Dry 2013				Wet 2014				Wet 2015				Dry 2015			
	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV
AFRICAN BUFFALO	3.22	3.20	10		0.17	0.16	6		0.12	0.09	9		1.86	1.38	12	78
CH1									0.27	0.27	6	100	4.57	3.22	12	70
CH2									0.00	0.00	4					
NG18	0.00	0.00	6		0.09	0.09	6	97	0.00	0.00	9		0.11	0.11	12	98
NG19	0.70	0.60	10	86	0.00	0.00	6		0.00	0.00	12		1.38	1.22	12	88
NG33_34	0.00	0.00	12		0.00	0.00	6		0.25	0.18	12	71	0.39	0.22	12	56
NG41	12.18	12.21	11	100	0.59	0.54	6	92	0.20	0.09	12	45	2.87	2.15	12	75
BABOON	0.19	0.18	10	92	0.95	0.83	6		0.70	0.58	9		0.38	0.31	12	
CH1									0.05	0.06	6	107	0.07	0.07	12	101
CH2									0.00	0.00	4					
NG18	0.17	0.11	6	66	3.80	3.31	6	87	0.34	0.35	9	101	0.41	0.36	12	87
NG19	0.11	0.14	10	130	0.00	0.00	6		2.47	2.13	12	86	0.00	0.00	12	
NG33_34	0.45	0.46	12	102	0.00	0.00	6		1.33	0.94	12	70	0.51	0.32	12	62
NG41	0.04	0.03	11	71	0.00	0.00	6		0.00	0.00	12		0.90	0.81	12	90
COMMON DUIKER	0.05	0.04	10		0.00	0.00	6		0.05	0.02	9		0.04	0.04	12	
CH1									0.00	0.00	6		0.16	0.18	12	111
CH2									0.32	0.13	4	40				
NG18	0.00	0.00	6		0.00	0.00	6		0.00	0.00	9		0.04	0.03	12	89
NG19	0.00	0.00	10		0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG33_34	0.04	0.06	12	148	0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG41	0.16	0.11	11	70	0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
COMMON REEDBUCK	0.17	0.09	10		0.00	0.00	6		0.23	0.12	9		0.09	0.05	12	
CH1									0.00	0.00	6		0.00	0.00	12	
CH2									0.00	0.00	4					
NG18	0.67	0.34	6	51	0.00	0.00	6		0.80	0.33	9	41	0.45	0.24	12	53
NG19	0.00	0.00	10		0.00	0.00	6		0.34	0.19	12	56	0.00	0.00	12	
NG33_34	0.00	0.00	12		0.00	0.00	6		0.25	0.17	12	70	0.00	0.00	12	
NG41	0.00	0.00	11		0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
ELAND	0.00	0.00	10		0.00	0.00	6		0.00	0.00	9		0.05	0.05	12	
CH1									0.00	0.00	6		0.23	0.23	12	101
CH2									0.00	0.00	4					
NG18	0.00	0.00	6		0.00	0.00	6		0.00	0.00	9		0.00	0.00	12	
NG19	0.00	0.00	10		0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG33_34	0.00	0.00	12		0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG41	0.00	0.00	11		0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
ELEPHANT	2.63	1.02	10	37	2.28	1.02	6	53	1.29	0.77	9		2.68	1.09	12	41
CH1									0.00	0.00	6		2.48	1.10	12	44
CH2									0.32	0.24	4	75				

	Dry 2013				Wet 2014				Wet 2015				Dry 2015			
	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV
NG18	3.00	1.23	6	41	5.30	2.07	6	39	0.29	0.30	9	104	2.42	1.09	12	45
NG19	2.53	0.76	10	30	1.99	0.75	6	37	3.67	1.34	12	36	0.80	0.33	12	41
NG33_34	3.70	1.69	12	46	0.47	0.32	6	69	2.59	2.32	12	90	3.13	1.18	12	38
NG41	1.29	0.39	11	30	1.34	0.92	6	69	0.91	0.42	12	46	4.59	1.78	12	39
GIRAFFE	1.27	0.49	10	51	0.81	0.50	6		1.14	0.55	9		1.08	0.48	12	44
CH1									0.65	0.69	6	107	0.46	0.22	12	48
CH2									0.00	0.00	4					
NG18	2.66	0.88	6	33	1.15	0.55	6	48	2.53	1.10	9	43	0.37	0.14	12	38
NG19	0.97	0.52	10	53	0.00	0.00	6		0.30	0.21	12	69	0.71	0.33	12	47
NG33_34	1.28	0.42	12	33	0.74	0.51	6	69	2.29	0.78	12	34	2.27	1.00	12	44
NG41	0.16	0.13	11	84	1.34	0.92	6	68	1.07	0.53	12	49	1.60	0.69	12	43
HIPPO	0.64	0.52	10	74	0.61	0.57	6		1.22	0.65	9		0.65	0.28	12	
CH1									0.00	0.00	6		0.00	0.00	12	
CH2									0.00	0.00	4					
NG18	0.75	0.46	6	61	0.00	0.00	6		1.38	0.71	9	51	1.38	0.65	12	47
NG19	1.34	1.34	10	99	0.87	0.61	6	71	3.97	1.57	12	40	1.64	0.56	12	34
NG33_34	0.21	0.17	12	81	0.13	0.18	6	132	0.21	0.12	12	59	0.00	0.00	12	
NG41	0.24	0.13	11	55	1.43	1.49	6	105	1.78	1.48	12	83	0.25	0.18	12	72
IMPALA	23.08	5.73	10	26	9.39	2.58	6	38	15.01	4.35	9	45	17.31	5.14	12	33
CH1									2.21	1.17	6	53	1.63	0.70	12	43
CH2									1.08	1.07	4	99				
NG18	13.06	3.39	6	26	15.98	3.48	6	22	20.49	6.10	9	30	16.53	7.32	12	44
NG19	32.80	10.25	10	31	13.61	4.65	6	34	28.41	6.83	12	24	22.81	7.65	12	34
NG33_34	35.78	6.38	12	18	6.60	1.17	6	18	27.06	6.62	12	24	29.60	6.65	12	22
NG41	10.66	2.89	11	27	1.34	1.03	6	77	10.77	4.30	12	40	15.99	3.40	12	21
KUDU	1.71	0.65	10	44	0.34	0.21	6		0.64	0.25	9		1.28	0.43	12	38
CH1									0.32	0.17	6	51	0.55	0.26	12	46
CH2									0.06	0.06	4	99				
NG18	2.00	0.88	6	44	0.62	0.41	6	66	1.03	0.46	9	44	1.53	0.46	12	30
NG19	1.51	0.45	10	30	0.35	0.26	6	75	1.45	0.46	12	32	2.05	0.49	12	24
NG33_34	2.76	0.87	12	31	0.40	0.16	6	40	0.96	0.33	12	35	1.41	0.47	12	33
NG41	0.56	0.40	11	72	0.00	0.00	6		0.00	0.00	12		0.86	0.47	12	54
OSTRICH	0.06	0.07	10		0.55	0.25	6		0.15	0.10	9		0.24	0.21	12	
CH1									0.22	0.14	6	63	0.36	0.18	12	49
CH2									0.00	0.00	4					
NG18	0.00	0.00	6		0.00	0.00	6		0.11	0.11	9	97	0.41	0.42	12	102
NG19	0.00	0.00	10		0.00	0.00	6		0.51	0.30	12	58	0.00	0.00	12	
NG33_34	0.25	0.26	12	107	0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG41	0.00	0.00	11		2.18	0.99	6	45	0.08	0.08	12	106	0.45	0.46	12	102
RED LECHWE	0.04	0.05	10		0.46	0.26	6		0.53	0.32	9		0.48	0.38	12	
CH1									0.00	0.00	6		0.00	0.00	12	

	Dry 2013				Wet 2014				Wet 2015				Dry 2015			
	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV
CH2									0.00	0.00	4					
NG18	0.00	0.00	6		0.00	0.00	6		2.47	1.41	9	57	0.26	0.21	12	79
NG19	0.16	0.21	10	129	1.82	1.03	6	56	0.68	0.53	12	77	0.96	0.51	12	53
NG33_34	0.00	0.00	12		0.00	0.00	6		0.00	0.00	12		1.20	1.20	12	100
NG41	0.00	0.00	11		0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
ROAN	0.03	0.02	10		0.00	0.00	6		0.00	0.00	9		0.08	0.12	12	
CH1									0.00	0.00	6		0.03	0.04	12	111
CH2									0.00	0.00	4					
NG18	0.00	0.00	6		0.00	0.00	6		0.00	0.00	9		0.22	0.17	12	75
NG19	0.11	0.09	10	84	0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG33_34	0.00	0.00	12		0.00	0.00	6		0.00	0.00	12		0.11	0.14	12	122
NG41	0.00	0.00	11		0.00	0.00	6		0.00	0.00	12		0.04	0.26	12	644
STEENBOK	0.51	0.22	10	56	0.14	0.12	6		0.22	0.09	9	60	0.52	0.19	12	47
CH1									0.11	0.06	6	59	0.07	0.04	12	68
CH2									0.38	0.16	4	41				
NG18	0.17	0.16	6	97	0.26	0.18	6	69	0.06	0.06	9	101	0.30	0.22	12	73
NG19	0.32	0.18	10	55	0.00	0.00	6		0.04	0.04	12	102	0.42	0.17	12	39
NG33_34	1.07	0.33	12	31	0.13	0.11	6	80	0.25	0.07	12	29	0.77	0.22	12	28
NG41	0.48	0.20	11	42	0.17	0.18	6	105	0.47	0.14	12	29	1.03	0.30	12	29
TSESSEBE	0.19	0.18	10		0.45	0.32	6		0.07	0.06	9		0.15	0.11	12	
CH1									0.00	0.00	6		0.00	0.00	12	
CH2									0.00	0.00	4					
NG18	0.17	0.16	6	97	0.00	0.00	6		0.29	0.28	9	98	0.26	0.19	12	73
NG19	0.00	0.00	10		0.00	0.00	6		0.04	0.04	12	89	0.17	0.17	12	104
NG33_34	0.25	0.18	12	72	0.88	0.37	6	42	0.00	0.00	12		0.30	0.15	12	51
NG41	0.36	0.36	11	101	0.92	0.91	6	98	0.08	0.05	12	67	0.04	0.04	12	98
WARTHOG	1.00	0.47	10	47	0.76	0.46	6		0.51	0.26	9	71	0.92	0.32	12	36
CH1									0.16	0.17	6	107	0.72	0.23	12	32
CH2									0.25	0.25	4	99				
NG18	1.25	0.76	6	61	0.00	0.00	6		0.29	0.28	9	98	0.52	0.28	12	53
NG19	0.86	0.41	10	48	1.04	0.58	6	56	0.73	0.29	12	40	1.17	0.37	12	32
NG33_34	1.32	0.43	12	33	0.13	0.12	6	89	0.21	0.10	12	47	0.90	0.20	12	22
NG41	0.56	0.27	11	48	1.85	1.15	6	63	1.42	0.49	12	34	1.31	0.54	12	41
WATERBUCK	0.60	0.40	10		0.23	0.15	6		0.39	0.17	9		0.52	0.30	12	
CH1									0.00	0.00	6		0.00	0.00	12	
CH2									0.00	0.00	4					
NG18	1.66	1.20	6	72	0.00	0.00	6		0.29	0.30	9	104	1.30	0.87	12	67
NG19	0.75	0.40	10	53	0.00	0.00	6		1.83	0.54	12	29	1.26	0.57	12	46
NG33_34	0.00	0.00	12		0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG41	0.00	0.00	11		0.92	0.62	6	67	0.20	0.18	12	90	0.04	0.04	12	92
WILDEBEEST	0.24	0.24	10		2.39	1.32	6		0.27	0.22	9		0.64	0.53	12	

	Dry 2013				Wet 2014				Wet 2015				Dry 2015			
	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV	D	SE	N	%CV
CH1									0.00	0.00	6		0.59	0.53	12	91
CH2									0.00	0.00	4					
NG18	0.00	0.00	6		0.09	0.09	6	105	0.06	0.06	9	98	0.04	0.04	12	105
NG19	0.16	0.16	10	96	0.00	0.00	6		0.04	0.05	12	107	2.05	1.58	12	77
NG33_34	0.25	0.22	12	90	0.00	0.00	6		0.00	0.00	12		0.00	0.00	12	
NG41	0.56	0.57	11	101	9.48	5.19	6	55	1.50	1.19	12	79	0.53	0.49	12	92
ZEBRA	0.22	0.18	10		1.83	1.14	6	78	5.26	2.64	9	61	4.40	2.17	12	52
CH1									3.72	2.42	6	65	15.46	8.60	12	56
CH2									0.25	0.25	4	99				
NG18	0.00	0.00	6		0.26	0.26	6	97	0.46	0.31	9	67	1.27	0.49	12	38
NG19	0.43	0.32	10	74	1.91	1.95	6	102	4.10	1.61	12	39	2.56	0.73	12	29
NG33_34	0.16	0.10	12	63	0.27	0.19	6	70	2.54	1.14	12	45	2.66	0.97	12	36
NG41	0.28	0.29	11	102	4.87	2.16	6	44	20.51	10.10	12	49	0.04	0.04	12	99

Appendix V: Survey Effort Recommendations

Buckland et al. (2011) provides an approach to use existing survey data to calculate the required effort to achieve a set coefficient of variation. We have used that equation to provide recommendations on survey effort by species within concessions and for wet and dry seasons.

Table A- 8. Full results of calculated recommendations of survey length needed to achieve a CV= 0.5 based on data from the 2015 wet and dry seasons; calculations based on Buckland et al (2011), equation 7.12.

Species and Concession	Dry 2015	Wet 2015
Elephant	**136**	**385**
NG 18	175	1144
NG 19	202	115
NG 33-34	92	139
NG 41	76	141
CH 1	170	-
Giraffe	**163**	**255**
NG 18	217	202
NG 19	246	465
NG 33-34	64	69
NG 41	128	285
CH 1	325	-
Impala	**30**	**49**
NG 18	45	29
NG 19	27	31
NG 33-34	13	35
NG 41	36	102
CH 1	127	
Kudu	**173**	
NG 18	170	
NG 19	130	
NG 33-34	175	
NG 41	217	
CH 1	498	-
Steenbok	**299**	
NG 18	498	
NG 19	428	
NG 33-34	158	
NG 41	111	
Warthog	**224**	
NG 18	403	
NG 19	151	
NG 33-34	165	
NG 41	176	
CH 1	192	
Zebra	**329**	**345**
NG 18	341	769
NG 19	161	143
NG 33-34	246	251
NG 41	570	217
CH 1	74	160

Appendix VI: Bird Point Count Survey Summary

This appendix provides addition information about bird surveys described in Chapter 2.

Bird Life Botswana Data Sheet

Bateleur Slaty Egret Lesser Flamingo Black-winged Pratincole White-headed Vulture Lappet-faced Vulture
Hooded Vulture White-backed Vulture Cape Vulture Martial Eagle Pallid Harrier Wattled Crane Grey Crowned Crane
Chestnut-banded Plover European Roller Kori Bustard Ground Hornbill Maccoa Duck African Skimmer Lesser Kestrel

Species Name	GPS co-ords South	East	Concession Area	Locality (place name)	Date	Time	# birds	Ad. M	Ad. F	Ad. ?	# Juv.	Observer	Comments

Please return to BirdLife Botswana: Peter Hancock, PO Box 1529, Maun. Contact Number: 6865618

Figure A- 11. Field survey data sheet used, adapted from BirdLife Botswana to record birds of concern

BIRD POINT COUNT - DATA SHEET

Concession:	**Date (d/m/y):**
Transect ID, Point Count #:	**Observers:**
GPS S:	**Start Temp. (°C):**
GPS E:	**Start Cloud Cover:**
Description of Location:	**Wind:**
	Habitat Code:
	End Temp. (°C):
Start Time:	**End Cloud Cover:**
Stop Time:	

RECORD ONLY BIRDS IN YOUR INVENTORY AREA	**[1]CUE CODES**	
	V	Visual
	S	Sound

Species Name	Total Count	Cue (code)[1]

Figure A- 12. SAREP bird point count survey field data sheet.

Table A- 9. Bird species recorded during point count surveys between 2013 and 2015.

Bird Species	Dry 2015	Wet 2015	Grand Total
Acacia Pied Barbet	3		**3**
African Barred Owlet	2		**2**
African Darter	3	10	**13**
African Fish Eagle	16	18	**34**
African Golden Oriole		3	**3**
African Grey Hornbill	63	81	**144**
African Harrier-hawk		2	**2**
African Hawk Eagle		2	**2**
African Jacana	41	42	**83**
African Marsh Harrier		1	**1**
African Mourning Dove		11	**11**
African Openbill	11	12	**23**
African Palm Swift	1	21	**22**
African Paradise-Flycatcher	2		**2**
African Pygmy Goose	2		**2**
African Red-eyed Bulbul	1		**1**
African Spoonbill	2	1	**3**
Alpine Swift		63	**63**
Amethyst Sunbird	3	1	**4**
Amur Falcon	1		**1**
Ant-eating Chat	1		**1**
Arrow-marked Babbler	42	39	**81**
Ashy Tit		3	**3**
Barn Swallow	86	179	**265**
Bateleur	7	23	**30**
Bearded Woodpecker	6		**6**
Black Crake		4	**4**
Black Cuckooshrike		1	**1**
Black-backed Puffback	4		**4**
Black-crowned Tchagra		1	**1**
Black-eyed Bulbul		3	**3**
Black-faced Oriole	1		**1**
Black-headed Oriole	1		**1**
Black-shouldered Kite		1	**1**
Black-tit Babbler	1		**1**
Blacksmith Lapwing	39	49	**88**
Blue Waxbill	20	9	**29**
Bradfield's Hornbill	10	5	**15**
Broad-billed Roller	1		**1**
Brown Snake Eagle	4	3	**7**
Brown-browed Sparrow Weaver	1		**1**
Brown-crowned Tchagra	1		**1**
Brown-hooded Kingfisher		2	**2**
Brubru	2	1	**3**
Burchell's Starling	68	285	**353**
Canary spp.	7		**7**
Cape Crow	1		**1**
Cape Glossy Starling	2	52	**54**
Cape Turtle Dove	974	628	**1602**
Cape Vulture		2	**2**
Cardinal Woodpecker		5	**5**
Carmine Bee-eater		1	**1**
Cattle Egret	6	26	**32**
Chinspot Batis		3	**3**
Common Sandpiper	3	6	**9**
Common Scimitarbill	2	1	**3**
Common Swift	1		**1**
Coppery-tailed Coucal	7	10	**17**
Crested Francolin	3	9	**12**
Crimson-breasted Shrike	9	7	**16**
Crowned Lapwing		5	**5**
Dark Capped Bulbul	1		**1**
Dickinson's Kestrel		1	**1**
Double-banded Sandgrouse	16		**16**
Egyptian Goose	30	39	**69**
Emerald Spotted Wood Dove	9	28	**37**
European Bee-eater		7	**7**
Familiar Chat	3		**3**
Fiery-necked Nightjar		1	**1**
Fork-tailed Drongo	106	111	**217**
Fulvous Whistling Duck		3	**3**
Garden Warbler	1		**1**
Giant Eagle-owl	1	5	**6**
Golden Bishop		1	**1**
Golden Oriole	2		**2**
Golden Weaver		1	**1**
Golden-breasted Bunting	2		**2**
Golden-tailed Woodpecker		7	**7**
Goliath Heron	2	1	**3**
Grand Total	2887	3814	**6701**
Great Egret	4	6	**10**
Greater Blue-eared Starling	4		**4**
Greater Honeyguide	1		**1**
Green Wood-hoopoe	13	21	**34**
Green-backed Heron	1		**1**
Green-capped Eremomela	1		**1**
Grey Heron	2	4	**6**
Grey Lourie	24	56	**80**
Grey Sparrow Weaver	2		**2**
Grey-backed Camaroptera	1	2	**3**
Grey-backed Heron		1	**1**
Grey-capped Eremomela	1		**1**
Grey-headed Kingfisher		5	**5**
Grey-headed Sparrow		8	**8**
Grey-rumped Swallow	1		**1**
Hadeda Ibis	2	4	**6**

Bird Species	Dry 2015	Wet 2015	Grand Total
Hamerkop	3	2	**5**
Hartlaub's Babbler	1	4	**5**
Helmeted Guineafowl	67	16	**83**
Hooded Vulture	1		**1**
House Sparrow	1		**1**
Kalahari Scrub-robin		1	**1**
Kori Bustard	4		**4**
Lappet-faced Vulture	1		**1**
Laughing Dove	10	15	**25**
Lazy Cisticola		1	**1**
Lesser Grey Shrike	2	1	**3**
Lesser Masked Weaver	4		**4**
Lilac-breasted Roller	64	55	**119**
Little Bee-eater	5	30	**35**
Little Egret	5	1	**6**
Little Grebe		2	**2**
Little Sparrowhawk		2	**2**
Long-billed Crombec		2	**2**
Long-tailed Shrike		1	**1**
Long-toed Lapwing	8	1	**9**
Magpie Shrike	18	8	**26**
Malachite Kingfisher		1	**1**
Marabou Stork		1	**1**
Marico Flycatcher	3		**3**
Marico Sunbird	2	2	**4**
Martial Eagle		2	**2**
Melba Finch		2	**2**
Meves's Starling	91	189	**280**
Meves's Starling	155		**155**
Meyer's Parrot	25	7	**32**
Namaqua Dove		2	**2**
Namaqua Sandgrouse	16		**16**
Neddicky		4	**4**
Ostrich	3	13	**16**
Pearl-spotted Owlet		25	**25**
Pied Kingfisher	13	7	**20**
Purple Roller	1	3	**4**
Pygmy Falcon		2	**2**
Red-backed Shrike	1	11	**12**
Red-billed Buffalo Weaver	10	28	**38**
Red-billed Firefinch		4	**4**
Red-billed Hornbill	103	125	**228**
Red-billed Oxpecker	7	21	**28**
Red-billed Quelea	24	669	**693**
Red-billed Spurfowl	107	202	**309**
Red-crested Korhaan	3	5	**8**
Red-crested Spurfowl	1		**1**
Red-eyed Bulbul			

Bird Species	Dry 2015	Wet 2015	Grand Total
Red-eyed Dove	11	120	**131**
Red-throated Canary	2		**2**
Reed Cormorant	5	3	**8**
Rufous-bellied Heron	1	1	**2**
Rufous-naped Lark	4		**4**
Sacred Ibis	4		**4**
Saddle-billed Stork	3	4	**7**
Sandpiper spp.	1		**1**
Scarlet-chested Sunbird	16	2	**18**
Sedge Warbler		2	**2**
Senegal Coucal		1	**1**
Shaft-tailed Whydah		5	**5**
Slaty Egret	1		**1**
Southern Black Tit	5	5	**10**
Southern Carmine Bee-eater	31		**31**
Southern Grey-headed Sparrow	5		**5**
Southern Ground Hornbill	9	1	**10**
Southern Masked Weaver		1	**1**
Southern Pied Babbler	2	12	**14**
Southern White-crowned Shrike	1	5	**6**
Southern Yellow-billed Hornbill	103	66	**169**
Spotted Flycatcher		3	**3**
Spur-winged Goose	10	15	**25**
Squacco Heron	16	3	**19**
Steppe Buzzard		3	**3**
Swainson's Spurfowl	3	23	**26**
Swallow-tailed Bee-eater	12	4	**16**
Swamp Boubou	2	2	**4**
Tawny Eagle	4	3	**7**
Unidentified Bird	65		**65**
Verreaux's Eagle-owl	1	2	**3**
Violet-eared Waxbill	1		**1**
Water Thick-knee	2	2	**4**
Western Barn Owl		3	**3**
White Crowned Shrike		1	**1**
White-Backed Vulture	26	5	**31**
White-bellied Sunbird	3	10	**13**
White-browed Sparrow-weaver	20	4	**24**
White-crested Helmetshrike	12	4	**16**
White-crowned Plover	3		**3**
White-crowned Shrike	6		**6**
White-faced Whistling Duck		60	**60**
White-fronted Bee-eater	13		**13**
White-headed Vulture		1	**1**
Woodland Kingfisher		1	**1**
Yellow-billed Kite	32	19	**51**
Yellow-billed Oxpecker	1	4	**5**
Yellow-billed Stork	1	4	**5**

Appendix VII: Community Trust Escort Guide Participation

We acknowledge and recognize the commitment and contribution of the 38 escort guides from across the concessions. Several have returned to the survey effort multiple times, advancing their expertise in the methodology, equipment as well as spending time monitoring the status of their concession areas.

Table A- 10. Individual escort guides from each concession have participated in the wildlife and bird surveys and associated training, with some returning for a second season (*), a third season (**) and a fourth season (***).

Year	Name	Trust/Concession Area
2013 (Feb-May)	Mokango Dikeledi Tumalano Hako Gothusitswemang Tando Maranyane Ntongwane Oneilwemang Sakoi	Sankuyo
	Tshotlego Masheto Monageng Chetiso Batwaetse Tshiamo Kebuelemang Gontshitswe Gakena Warona Mogapi Tiny Kebuelemang Baleofi Mogodu Jane Tumelo Kago Obiditswe Reetsang Gakena Onalethata Ruthano Mmoloki Ditirwa	Mababe
	Mmapula Bahenyi Oagile Banda Ditshebo Mojeremane Johnson Sasaya Oatshela Ikageng Gaborongwe Joseph Mothala Amos Seteng Sasaya Thato Amos Onkgopotse July Isaac Duma Bankeme Gaarekwe	Khwai
2013 (Sep-Dec)	Tumalano Hako* Mokango Dikeledi* Maranyane Ntongwane* Baefesia Tando	Sankuyo
	Barutegi Xhawe Batwaetse Tshiamo Kebuelemang* Kago Obiditswe* Baleofi Mogodu* Reetsang Gakena* Jane Tumelo* Warona Mogapi*	Mababe
	Mmapula Bahenyi* Oagile Banda* Oatshela Ikageng* Thato Amos* Johnson Sasaya* Onkgopotse July* Ditshebo Mojeremane* Mothala Amos*	Khwai
	Simeon B	Chobe Enclave
2014 (Mar-Apr)	Oneilwemang Sakoi* Keoagile Gaolathe Maranyane Ntongwane**	Sankuyo
	Tshotlego Masheto* Kago Obiditswe** Monageng Chetiso* Reetsang Gakena** Mmoloki Ditirwa* Tiny Kebuelemang* Tuelo Kebuelemang	Mababe
	Oagile Banda** Seteng Sasaya*	Khwai
2015 (Feb-May)	Baefesia Tando* Keoagile Gaolathe*	Sankuyo
	Tshotlego Masheto** Mmoloki Ditirwa **	Mababe
	Oatshela Ikageng** Gaborongwe Joseph* Bokhutlo Sauta Boifang Nkape Seteng Sasaya** Thato Amos** Lindy Jack	Khwai
2015 (Sep-Dec)	Keoagile Gaolathe** Mokango Dikeledi**	Sankuyo
	Monageng Chetiso** Mmoloki Ditirwa***	Mababe
	Bokhutlo Sauta * Thato Amos*** Seteng Sasaya***	Khwai

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Round River Conservation Studies is an ecological research and education organization whose goal is the formulation and implementation of conservation strategies that conserve and restore wildness.