

Madikwe Game Reserve Elephant Survey

Deon Joubert, Hannes Naudé, 7 July 2017

The Elephant Survey System (ESS) is an aerial image capturing and processing platform designed with the specific aim of estimating the size of an elephant population in a cost and time effective manner. This system was used to conduct a survey within the Madikwe Game Reserve during June of 2017. Because this was the first full scale survey conducted using the system with a new capture rig [1], several independent surveys were flown to allow for possible technical teething issues. This report focuses exclusively on detailed results for the third sortie, which was conducted on the 13th of June between 9h35 and 11h25. Similar analyses will eventually be completed for each of the sorties flown and the results can potentially be combined to provide a more accurate final estimate.

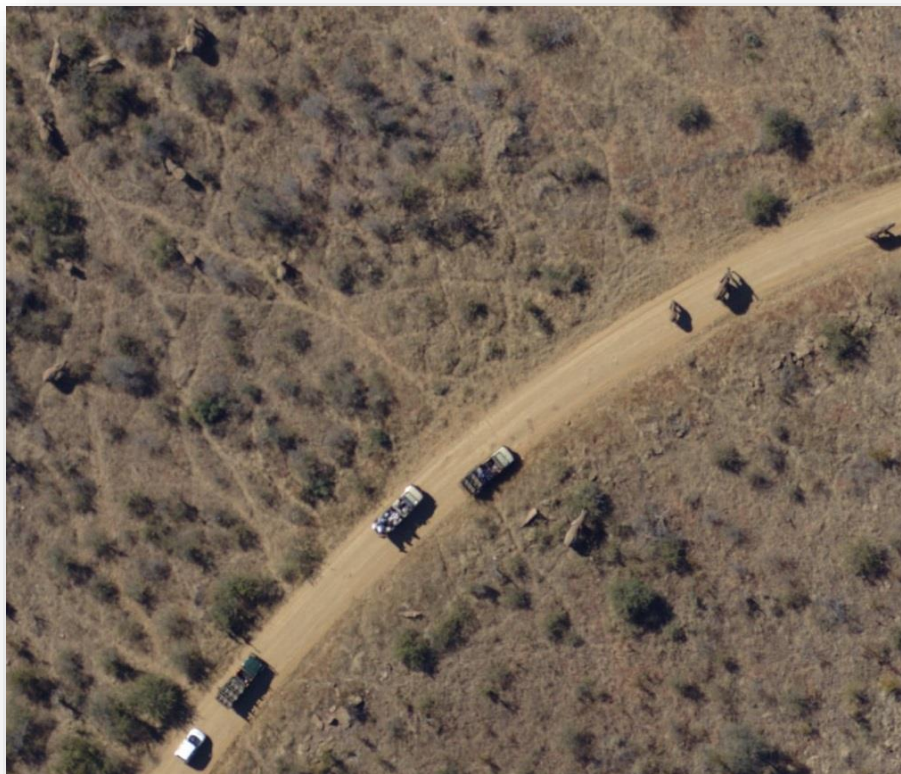


Figure 1. Enlarged section of an aerial image gathered during the Madikwe Game Reserve Elephant Survey.

During the sortie, a total of 2174 observations of 477 unique elephants were generated. We utilised a slightly modified version of the simple estimate method as described in [2], to estimate the total elephant population of Madikwe at 1348 with a standard error of 128. We expect that by using more

sophisticated statistical techniques, and incorporating the additional data that has not yet been processed, it would be possible to reduce the standard error further.

Section 1 of this report provides a brief overview of the operation of the ESS. Details on the survey methodology are explained in Section 2. The results are presented and discussed in Section 3 while future work is discussed in Section 4.

1 Overview of the ESS

The ESS collects visual images from aircraft-mounted cameras, and through processing by a deep neural network as well as verification by human operators, identifies elephants within the images. By statistically analysing the occurrence of elephants within the images, an estimate of the population is obtained.

The aircraft currently used is the SkyReach BushCat Light Sports Aircraft (LSA) [3], shown in Figure 2. The BushCat is well suited for survey work in remote regions as it can use standard 95 octane petrol (which is easier to obtain than aircraft fuel) and can land and takeoff from short dirt strips.



Figure 2. SkyReach BushCat.

An overview of the operation of the ESS is shown in Figure 3. Images are collected using the capture rig mounted within the BushCat (as seen in Figure 5), after which the data is copied onto a powerful desktop computer for off-line processing. The data capture equipment consists of three Canon EOS 6D Cameras, a laser altimeter and a Raspberry Pi computer. The Canon cameras are equipped with 85 mm f/1.8 Canon lenses and have built-in GPS receivers. The laser altimeter provides accurate altitude measurements at low altitudes while the GPS altitude readings are sufficient for higher altitudes. The Raspberry Pi is used to manage and synchronise the data recorded from the sensors.

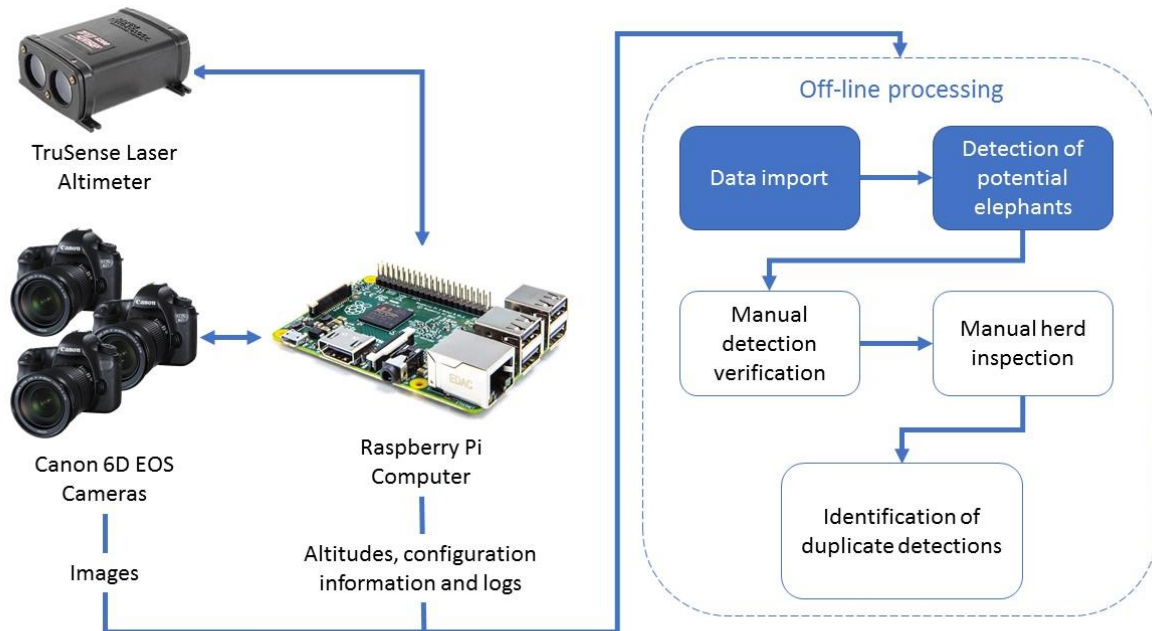


Figure 3. Flow diagram illustrating the operation of the ESS.

During the off-line processing, a deep neural network processes the images and generates heatmaps. These heatmaps indicate the likely location of elephants within the images, an example of which is shown in Figure 4. The possible elephant locations are then extracted as detections which are presented to a human operator in the ESSWeb browser-based application. The human operator steps through the images, confirming or rejecting the proposed elephant detections, while also checking images with confirmed detections for any additional elephants, as seen in Figure 6.

The cameras capture images at a relatively high rate, which results in overlapping images covering the same region multiple times. Having the images overlap is advantageous as complete ground cover is ensured and elephants can be verified across multiple images. However, as the same elephants are detected multiple times over several images, it is necessary to align the images and match the duplicate elephants across these images to obtain a set of unique elephant sightings. Statistical analysis of the observed elephants and their locations then results in an estimate of the elephant population within a park.

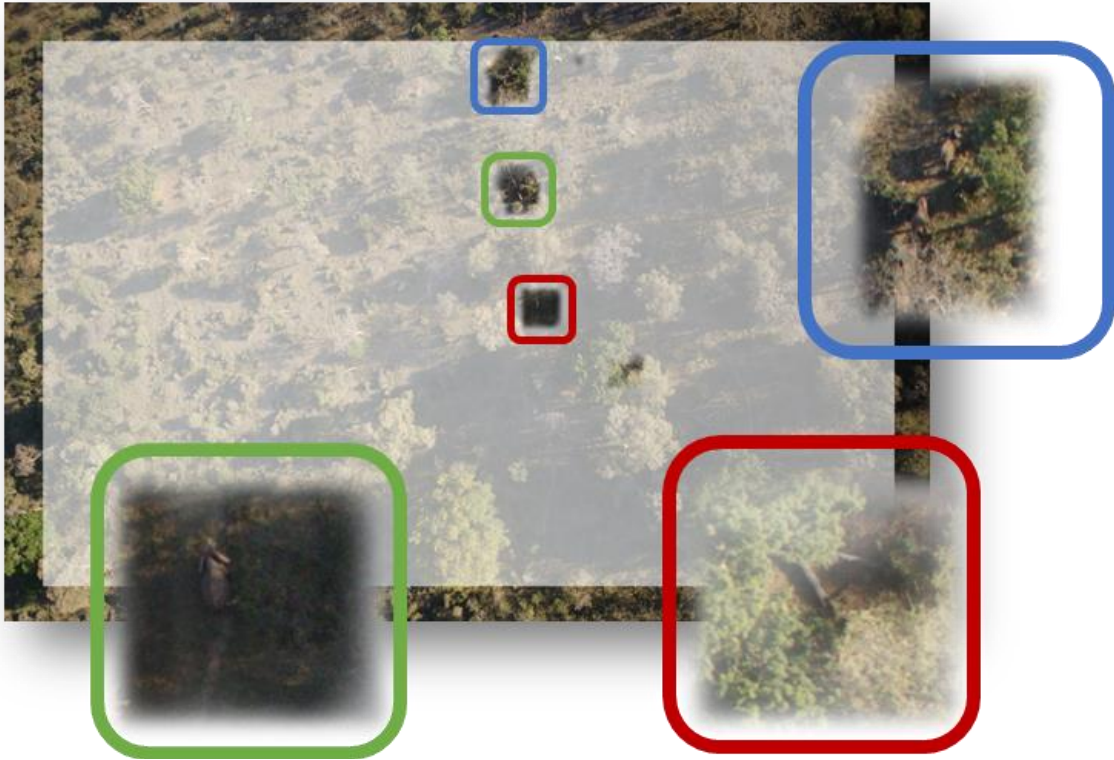


Figure 4. An example of a generated heatmap, overlaid onto a visual image, highlighting the likely locations of elephants within the image. Enlarged portions of these likely locations are also shown. Note the incorrect detection highlighted in red, which necessitates human verification.



Figure 5. ESS data capture rig mounted in a BushCat LSA.

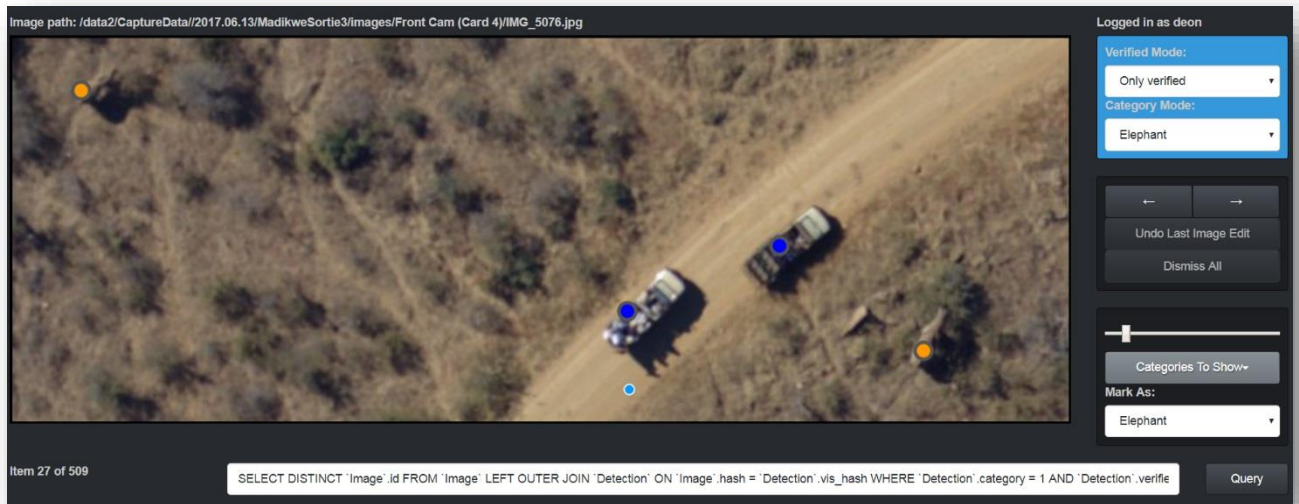


Figure 6. Screen capture of ESSWeb, used to verify the detections generated by the neural network.

2 Survey Methodology

The survey in the Madikwe Game Reserve was conducted from the 12th to the 14th of June 2017. The survey team consisted of:

Name	Role
Mr Mark Paxton	Pilot of the BushCat
Mr Hannes Naudé	Technical Support
Mr Deon Joubert	Technical Support

Five survey data collection flights, or sorties, were flown. The transects flown during each of the sorties were designed so that the images recorded would cover approximately 40% of the game reserve. The transects were oriented from East to West to be perpendicular to the Limpopo river, as can be seen in Figure 7. Of the five sorties, the third sortie was selected to be processed first, since it was free of technical glitches and was performed during optimal conditions.

The airplane took off and landed at the Madikwe Eastern Airstrip during the survey. After landing, the captured images were checked and backed up at the Madikwe Park Headquarters, where the desktop computer had been setup.

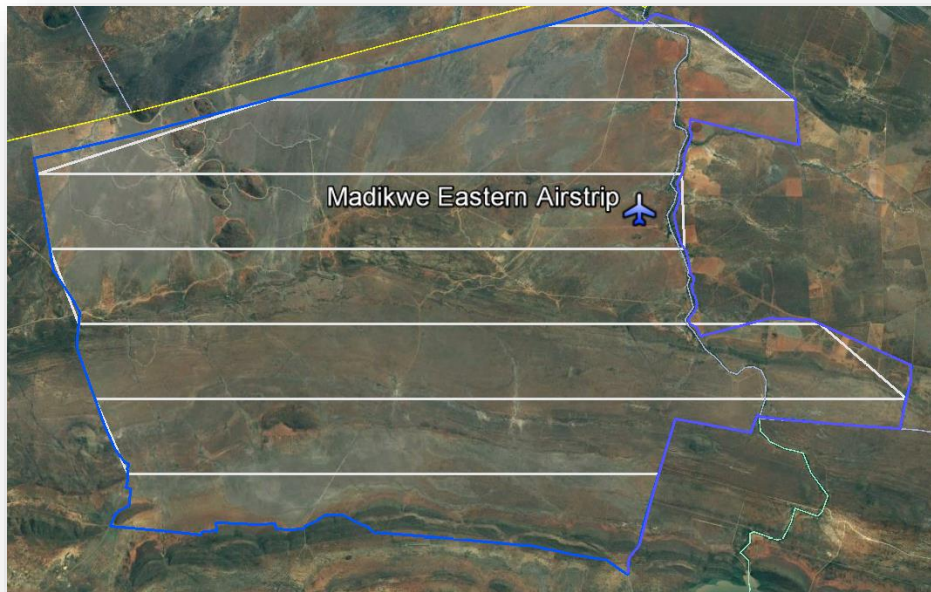


Figure 7. Google Earth image of the Madikwe Game Reserve, with the set of transects flown during the processed sortie indicated in white.

3 Results

Table 1 shows details on the processed sortie. Although many more images were recorded, only the stated 6835 images were captured during transect traversals at the desired altitude. Generation of the heatmaps took place over a weekend, with human verification of the detections taking approximately 16 man hours. Alignment and deduplication took about 8 man hours. This process will in future be streamlined and semi-automated.

Sortie Information	
Time of take-off	09:35
Time of landing	11:25
Total flight time	1:50
Transect images	6835
Area covered by images	260 km ²

Table 1. Sortie Information

One of the advantages of the ESS is that the data recorded and processed remains on hand and can be revisited at a later stage. Figure 8 shows a montage of all the unique elephant sightings, which can be reviewed and discussed by experts long after the survey work was originally conducted. Furthermore, the information obtained during the survey can be utilised for goals other than population estimation. Figure 9 shows the approximate locations of the elephants seen during the

sortie, which together with the time information of each image capture can provide insight into elephant behaviour across the park.

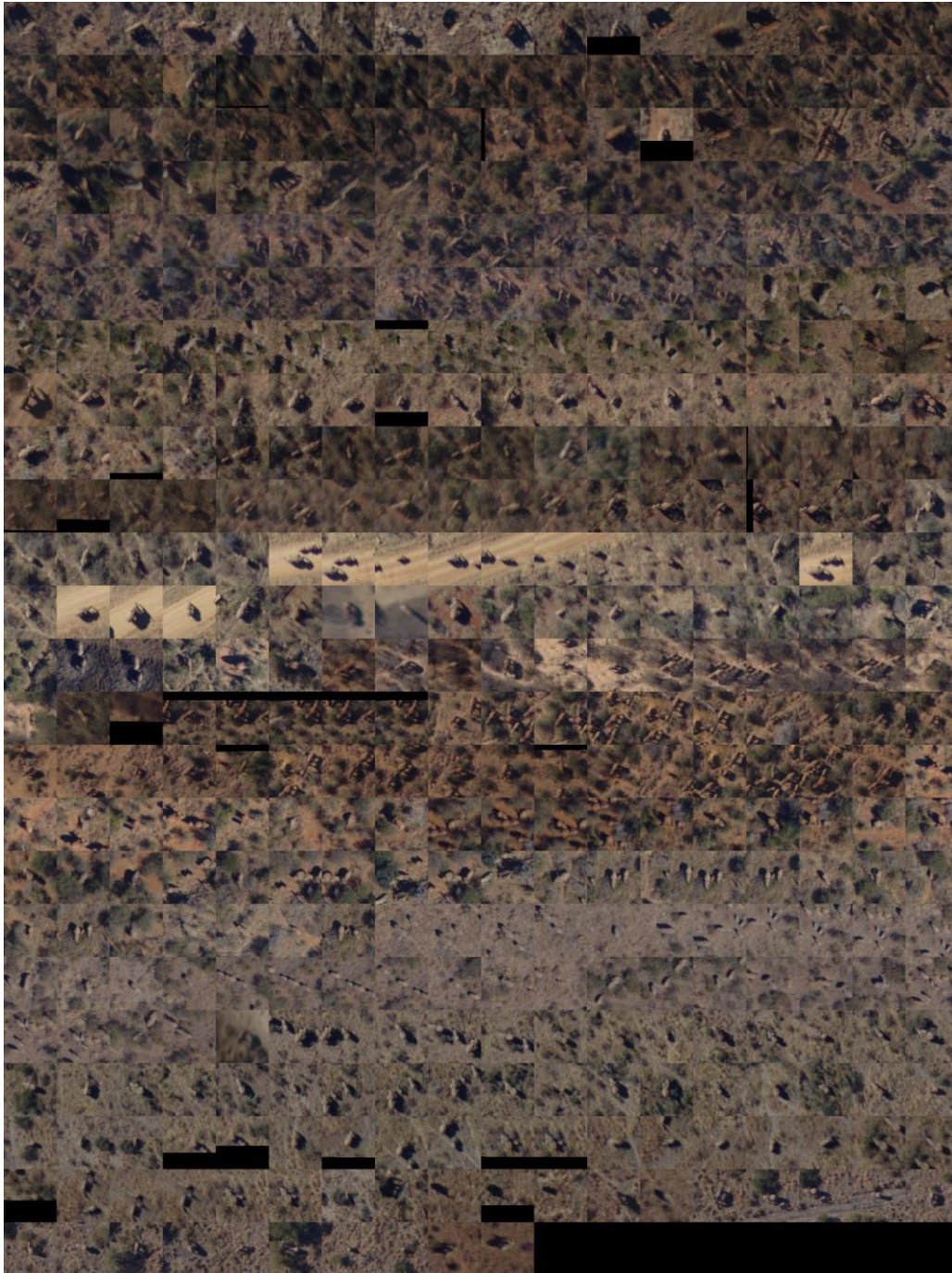


Figure 8. All unique elephant sightings identified in the sortie images.

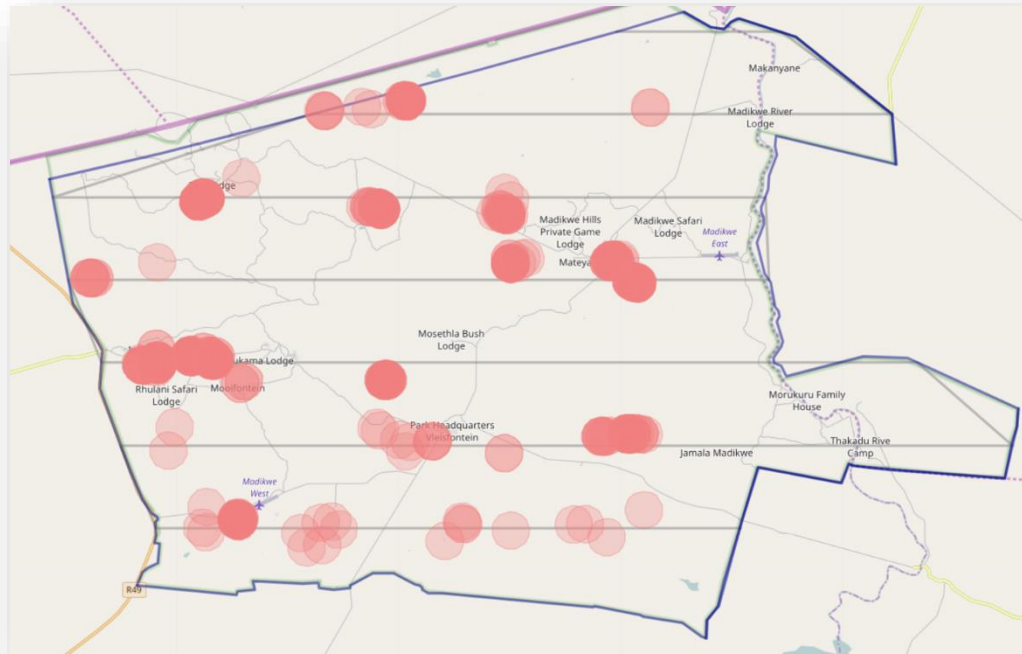


Figure 9. Approximate location of elephants identified from the sortie images, with a darker circle indicating a denser congregation of elephants.

4 Conclusion

From images collected during one of flights of the survey of the Madikwe Game Reserve, the elephant population can be estimated as 1348 with a standard error of 128.

This survey was performed using less than 2 hours of flying time of a cheap-to-operate light sport aircraft, and about 24 man hours of post-processing (much of which is unskilled labour, which could be performed by volunteers). While we believe that the post-processing cost can be reduced dramatically, it should be clear that even in its current state the ESS represents a significantly cheaper method for performing aerial elephant counts. In addition, the estimates produced in this way are more defensible, more accurate and more precise than those from a comparable manual survey.

The recorded data could also be used for a variety of other wildlife management related tasks, such as monitoring changes in vegetation cover and types over time, detecting unauthorised human presence and finding carcasses.

In future, we aim to improve the underlying neural network both in terms of processing time and accuracy. The user interface will also be expanded to take further advantage of the overlap between images and duplicate detections of the same elephants.

5 Acknowledgements

We would like to thank Mr. Paul Maritz for sponsoring the development of this system and this survey. Our gratitude is also extended to Mr. Pieter Nel from the North West Parks Board and Mr. Moremi Keabetswe from the Madikwe Game Reserve for their assistance in organising this survey as well as for the usage of their facilities. Furthermore, we would like to thank the staff at Moseitha Bush Lodge for their assistance during our stay there.

6 References

- [1] D. Joubert, C. Potgieter and H. Naudé, "Development of the TriCap Multicamera Image Capturing System," Innoventix Consulting, 2017.
- [2] G. Caughley, "Sampling in Aerial Survey," *The Journal of Wildlife Management*, pp. 605-615, 1977.
- [3] SkyReach, "BushCat Light Sport Aircraft Specifications," SkyReach, 2015.