FIELD NOTES

Using drones as ground-based camera systems with multiple coordinated sensors to study African elephants (*Loxodonta africana*)

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Introduction

Advances in drone technology over the last two decades have enabled the collection of a wide variety of ecological data with increased accuracy while reducing overall costs (Watts et al. 2012; Christie et al. 2016; Hodgson et al. 2016; 2018). Elephants are ideal candidates for drone-based monitoring due to their size, making them easily visible from a height (Koh and Wich 2012). However, there are concerns over the potential for drone-generated noise, which induces a fear response in elephants due to its perceived resemblance to the sound of swarming bees, ultimately altering the behaviour of elephants under observation. Furthermore, the majority of commercially available drones have relatively short flying times of around 30 minutes before battery depletion occurs, which puts limits on the length of time that elephants can be studied from drones. This concept paper discusses a novel use case for drones in which their cluster of integrated sensors is used to collect valuable data on elephant physiology and morphology without the drone being airborne—and thus without generating any propeller noise. Additionally, it provides the advantage of longer observation periods than would be possible if the drone were flying. Here, we present this technique solely in the context of data collection on elephant physiology and morphology. The potential applications of this method are manifold and could extend to other species of appropriate size (e.g. rhinos) across different landscapes.

Many commercial drones have a carrying capacity of some kind (defined as a payload), often in the form of high-performance cameras and sensors with the ability to record data in non-visible spectra (Esposito et al. 2021; Tuğrul 2023). Sensor integration is already a built-in feature in most drones, with gyroscopes, accelerometers, and magnetometers combining with GPS data to guide the drone's flight path and adjust its speed and direction (Tuğrul 2023). In addition, on-board deep learning processors can use sensors to enable object tracking, which is increasingly commonplace across drones of different makes and models (Tang et al. 2023). Consequently, the sophistication of drone cameras and sensors creates a wealth of potential applications for this

integrated data, which can be even more useful when recorded at ground level.

A significant issue with flying drones over wildlife is the noise they produce, which can disturb the species they are being used to observe (Duporge et al. 2021; Hodgson and Koh 2016). Elephants are disturbed if drones are flown in close proximity to them and will flee in response (Hahn et al. 2017), but show some tolerance to a drone flown at a distance (Bennitt et al. 2019; Hartmann et al. 2021; Mesquita et al. 2022). This disturbance can be mitigated by using a drone on the ground, and disturbance levels can be further kept to a minimum if the target animals are already habituated to the method used to collect data (Blumenstein 2016).

Methods

For our study, we used a DJI Matrice M30T quadcopter drone (hereafter M30T; DJI, Shenzhen, China) because its payload contains both an optical zoom camera and a laser rangefinder, both of which are essential for accurate morphometric data collection. The zoom camera has a 1/2" CMOS sensor with 48M effective pixels, and a focal length equivalent of 113–405mm, while the laser rangefinder can detect objects from 3–1,200 m with an accuracy of $\pm (0.2\,\text{m} + D \times 0.15\%)$, where D is the distance to a vertical surface.[1]

This study was conducted in the Samburu and Buffalo Springs National Reserves (NR), northern Kenya, which is home to a population of at least 744 individually identified elephants, that have been studied continuously since 1997 (Wittemyer 2001). We collected morphometric data from 156 elephants on 25 different occasions, resulting in a total of 220 images for analysis. Images were taken during daylight hours between 10.00 am and 5.00 pm. Given that elephants in Samburu NR and Buffalo Springs NR are already habituated to the presence of vehicles (Goldenberg et al. 2017; Wittemyer et al. 2005), we were able to position ourselves at close range to the elephants. This distance ranged between 3.5 m and 172.3 m, with

a mean of 27.4 m, and was dependent on factors such as the size and dispersal of the elephant group, as well as vegetation density and terrain.

The drone was placed in different positions depending on the configuration of the vehicle used, but included: i) the roof via an open hatch; ii) a bench in the rear; or iii) held in a raised position by the observer. All positions ensured that the drone camera had an unobstructed view of the target elephant. We used the drone for two main objectives: i) measuring the shoulder height of an elephant; and ii) thermal imaging.

Shoulder height measurements

To measure the shoulder height of individual elephants we positioned the vehicle at close range to the target elephants and enabled the M30T's laser rangefinder function (Fig. 1A). The rangefinder crosshairs were visually aligned on the upper part of an elephant's front leg, approximately in the middle of the humerus, while ensuring that both the bottom of the elephant's foot and the top of the shoulder were visible in the frame. Pictures were then taken with the elephant perpendicular to the camera, with a simultaneous recording of the rangefinder reading. This coordination meant that the pictures and measurements could be cross-referenced, allowing accurate calculation of elephant shoulder heights using digital photogrammetry.

We calculated the drone image resolution at various distances by comparing the height in pixels to the actual height of a known object, resulting in an equation describing the resolution (cm/px) as a function of distance to the object (m). With repeated measurements, we found that this process had a measurement accuracy ranging from ±0.1cm at a distance of 5 m to ±1.2 cm at 120 m, while the error of the rangefinder could result in a difference in resolution of ± 0.0026 cm/px at 5m, to ± 0.0048 cm/px at 120 m.

We measured the height of the elephant's shoulder in pixels as a straight line from the top of the shoulder to the bottom of the foot (Fig. 1b), and then using the resolution equation, we could estimate the elephant's shoulder height in cm using the distance from the rangefinder. Previous morphometric studies of wildlife have encountered challenges with data accuracy when using a camera and rangefinder independently, since it can be difficult to ensure that they are both exactly the same distance from the study subject and differences in focal lengths must be accounted for (Della Rocca 2007; Shrader et al. 2006). The combination of a camera
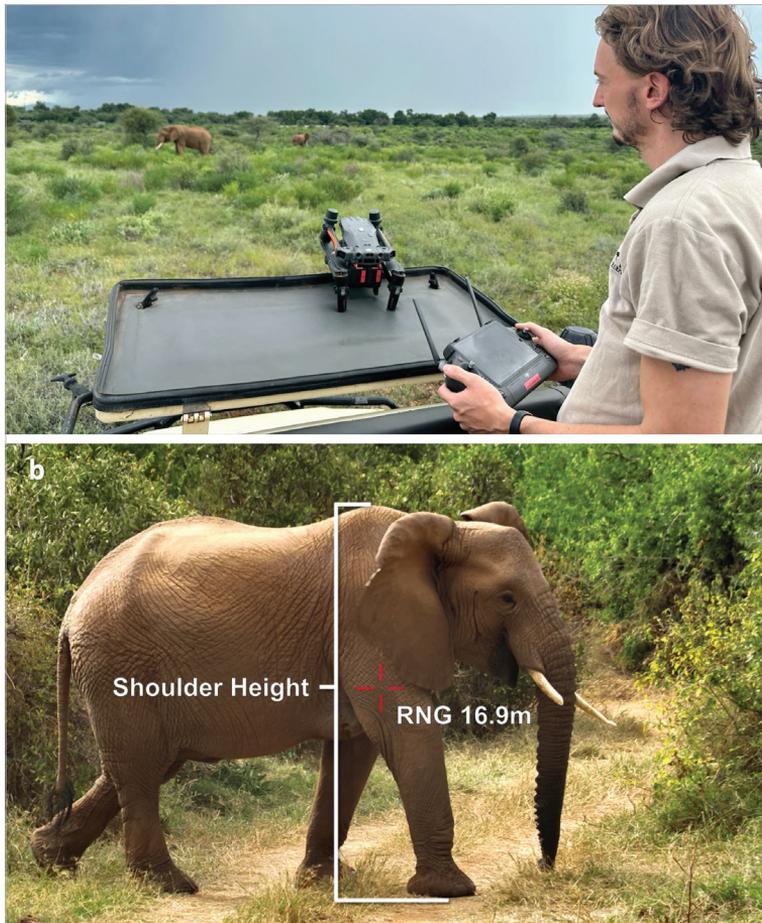

Figure 1. Using the drone from the roof of a vehicle to calculate shoulder height (a); and example shoulder height measurement (b); where shoulder height is measured as a straight line from the top of the shoulder to the bottom of the foot.

and laser rangefinder contained within the same payload made this calculation straightforward, eliminating much of the potential error if it were to be recorded with an independent camera and rangefinder. We found that height measurements made with the drone were 25.6% more accurate than measurements made with a separate rangefinder and DSLR camera. The drone was able to estimate the height of a known object with an average accuracy of ±0.76 cm, while the independent camera and rangefinder had an average accuracy of ±1.02 cm.

Elephant thermal imaging

We took high-resolution infrared footage of elephants, again without the need for an aerial drone. The M30T is equipped with a thermal camera with 640×512 resolution, which results in relatively poor image quality for detailed analysis when the drone is at altitude but offers much greater detail when used at close range (Fig. 2). For example, it could be clearly seen that the surface temperature was lower on the outer margins of the ears (where heat dissipation generally occurs). This opens the possibility of making detailed analyses of elephant surface body temperatures, heat dissipation techniques and temperature differences between individuals. Thus, by approaching elephants in a vehicle and using the drone in the same way as described above, we were able to obtain thermal footage with a level of detail which would otherwise have been impossible without disturbing the elephants, or without acquiring a highly expensive thermal camera (carrying no additional sensors, unlike the drone).

Figure 2. Thermal image of elephants when taken from the DJI M30T at close range (<10 m).

Conclusion

The specifications of each drone will ultimately dictate its suitability as a ground-mounted camera, but the majority of commercially available drones are small enough to allow for the possibility of this. Mounting options other than those described in this paper could include a fixed position on a vehicle or a telescopic boom, both of which would provide a stable and secure platform to operate the camera. Other techniques, such as placing the drone on a hard, flat surface, the use of a harness, or simply holding the drone, could offer an inexpensive, time-efficient and low-disturbance method to observe elephants. In addition, there can be a considerable cost-benefit advantage in purchasing a drone equipped with an array of built-in sensors, rather than individual pieces of equipment, which could together outweigh the cost of a drone, and without the additional versatility that the drone brings as an aerial platform.

The use of drones without being airborne under their own propulsion extends to being mounted on manned aircraft, thus significantly expanding the area over which data can be collected when compared to ground-based methods, such as those described in this paper, or if flying using the drone's own propulsion. There are a number of improvements that this technique could bring to aerial monitoring and wildlife surveys versus traditional camera options, which typically have fixed positions and settings on aircraft. These include the native integration of numerous sensors as well as the stability afforded by a drone's gimbal and the resultant improvement in footage quality, in addition to the capacity for in-flight adaptability by using the drone's remote controller to adjust the camera's direction and change its settings according to the research objective.

Drones are becoming an increasingly important tool in elephant research and conservation, with their sophisticated cameras and in-built sensors enabling the collection of critical baseline data such as body condition, morphometrics and growth curves with centimetre-level precision. This accuracy can be further enhanced by using drones on the ground, informing vital metrics such as population health and stress level measurements. Crucially, our technique of using drones as a ground-based data collection tool expands the scope of data that elephant researchers can collect while minimizing disturbance to elephants or other target species.

In conclusion, the deployment of drones as ground-based cameras has several advantages which could be of use to researchers using this technology. Advances in camera and sensor capability have made drones a tool that can outperform many DSLR cameras while offering the versatility to record many different types of data at once. The method outlined in this paper demonstrates one that can be easily applied to a range of research objectives. We recommend that researchers consider the use of ground-based drones as a safe, effective and low-disturbance method to gather empirical data for a wide range of wildlife observations.

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