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Surveying Arboreal Fauna with RPAS Thermal Imaging

Research to improve the detectability of fauna to support forestry monitoring and operations

June 2023

Acknowledgement of Country

The Department of Planning and Environment acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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More information

NSW Wildlife Drone Hub: The NSW Wildlife Drone Hub connects wildlife managers with emerging drone technology.

Citation

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Summary

This report describes a study conducted by the NSW Department of Planning and Environment (DPE) on behalf of the Natural Resources Commission. The study examined the use of Remotely Piloted Aircraft Systems (RPAS), or drones, to detect koalas and greater gliders.

Drone surveys were conducted within the Kalateenee State Forest and Doyle's River State Forest in northern coastal NSW. The NSW Wildlife Drone Hub operated drones fitted with thermal cameras to conduct surveys within 21 plots (25ha) within Kalateenee and 12 plots (25ha) within Doyle's River.

The Kalateenee plots targeting koalas were nominally surveyed over three consecutive nights in an effort to collect information on detectability. The total survey effort at Kalateenee was 1,700ha. The drones detected 68 koalas, of which 36 were verified by drone or on-ground inspection. The University of Newcastle is undertaking research with the Kalateenee State Forest RPAS dataset to spatially model koala occupancy and calculate the probability of detection for koalas. However, the results will be reported elsewhere.

The Doyle's River plots targeting greater gliders and located 48 animals, 13 of which could be verified by drone or ground teams. Greater gliders were more challenging to verify, as they often moved before ground teams could confirm species identity due to their high mobility.

Improvements in the cost and performance of drone technology have made existing cost/benefit modelling (Howell, et al., 2022) even more advantageous for the use of drones for surveying koala abundance. The NSW Wildlife Drone Hub now recommends drones be fitted with spotlights (>3000 lumens) that follow optical zoom colour sensors for arboreal species identification. The combination of colour and thermal imagery allows most detections to be verified using drones. This further improves drone survey cost-effectiveness and enhances the safety of field personnel.

Background

This study is part of broader research efforts to use technology to improve the detectability of fauna in support forestry monitoring and operations. Further information on the Coastal IFOA Monitoring Program can be found at https://www.nrc.nsw.gov.au/ifoa-mer.

This study addresses Question 2 of the IFOA Research Monitoring Strategy, "Can technology improve the probability of detection for a range of species in forestry operations?".

Drones mounted with thermal imaging cameras show promise as an accurate and highly cost-effective technique to survey koala abundance (Beranek et al., 2020; Witt et al., 2020; Howell et al., 2022). Koalas potentially make excellent candidates to be surveyed by drones because they are large-bodied, have distinct morphology, and are sedentary, reducing confusion with other animals when analysing images.

Two previous studies found that drones with thermal imaging cameras could have a higher koala detection rate than diurnal koala searches (Witt et al., 2022; Corcoran et al., 2019). However, the use of this technology for surveying koala's density is still in development.

The available resources allowed three weeks of field survey in two locations with two target animal species. Estimating the probability of detection is out of scope, as was a survey of a wider range of habitat types through the Coastal IFOA region. Locations for surveys were chosen in consultation with ecologists from the NSW Forest Corporation.

All drone surveys were conducted by the NSW Wildlife Drone Hub (the Drone Hub). The Drone Hub enables land managers in New South Wales to access drones and pilots to survey biodiversity and encourages the consistent uptake of drones.

The Drone Hub provides specialized training enabling drones to detect wildlife and vegetation. The Drone Hub manages the data collected by drones and provides digital tools and advanced artificial intelligence (AI) analytics. Contact details for the Drone Hub are available in the Appendix.

Aims

The aims of this study were to:

1. Survey koalas using drones in accessible areas of the Kalateenee State Forest, NSW.
2. Estimate the number of koalas within the areas surveyed and provide a map of locations.
3. Trial drones with thermal cameras for detecting greater gliders.
4. Trial a field method for validating detections of highly mobile animals in real-time.

Study Areas

Kalateenee State Forest is on the mid-north coast of New South Wales (NSW). Kalateenee State Forest covers around 1,400 hectares and is managed by the New South Wales Forestry Corporation, which aims to ensure sustainable forest management practices.

Doyle's River State Forest covers about 36,000 hectares and is located 100km west of Port Macquarie. The New South Wales Forestry Corporation manages Doyle's River State Forest.

Methods

A quadcopter drone (Mavic 2 Enterprise Advanced) equipped with a 640 × 512-pixel thermal camera was deployed at each site after 8 p.m. when the ambient temperatures were low (Figure 1). Terrain following flights were programmed using the software program UGCS and flown in a lawn mower pattern (Figure 2) as per Beranek et al. (2021) and Witt et al. (2021).

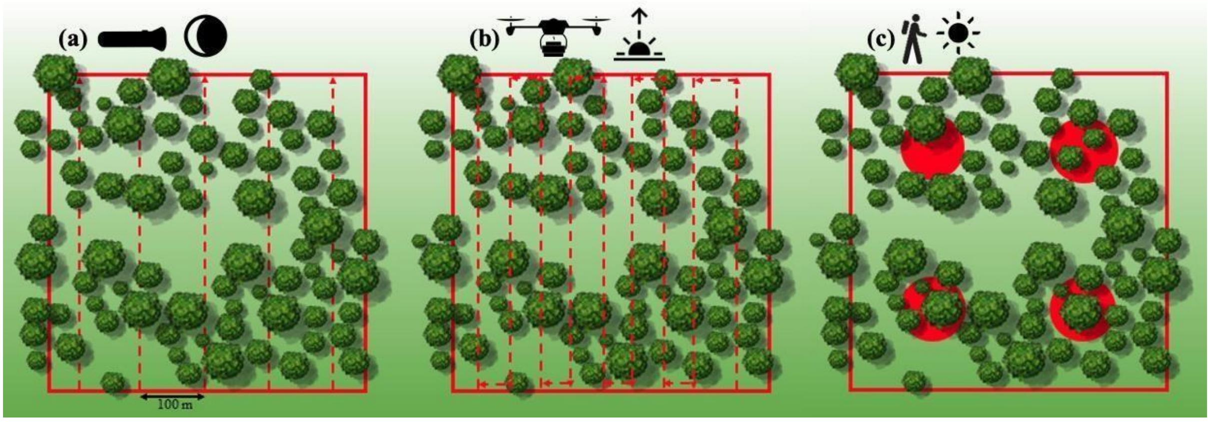

Figure 1. We followed the methods established in Witt et al., 2020, where we found drone-derived thermal imagery (b) outperformed traditional survey methods including spotlighting (a) and scat surveys (c)

For each study area a series of 25ha plots were flown in a checkerboard pattern along an approximately north-south bearing. The drones were programmed to follow the terrain at an elevation of 65m (AGL) Figure 2. Drone flights are terrain following, allowing the drones to survey relatively autonomously regardless of the terrain (Imagery source: Google Earth). Each detection was recorded by the pilot in charge using a mobile device app, Survey123 (Figure 3), which allows for near real-time capture of species sightings.

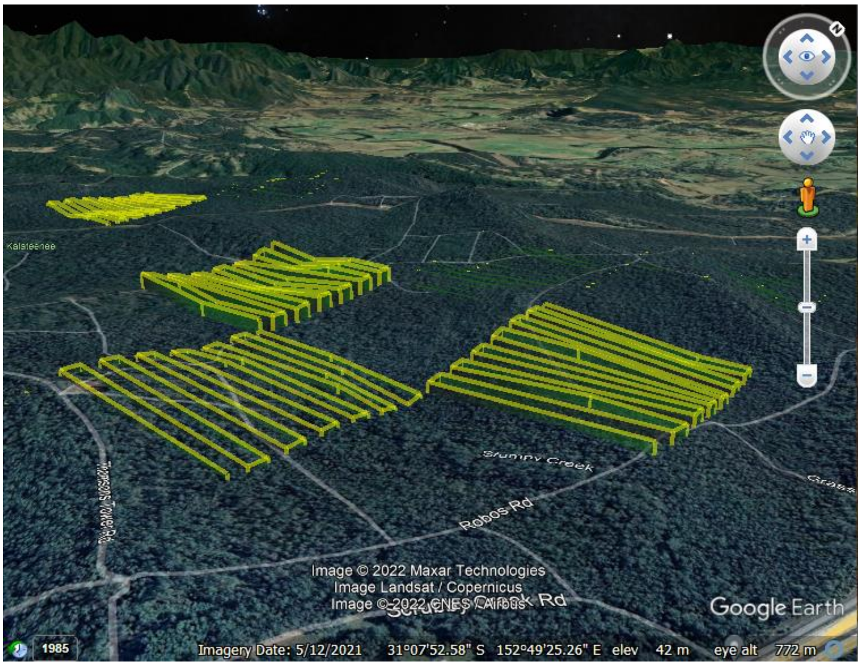

Figure 2. Drone flights are terrain following, allowing the drones to survey relatively autonomously regardless of the terrain (Imagery source: Google Earth).

Department of Planning and Environment
Fact sheet

NSW GOVERNMENT

Filling a Drone Flight Detection Survey

Per Mission Information

1. Fill in the Mission Name, Date, Location (Use map icon if phone GPS fails, include in additional info as last resort), Drone Name, Pilot Name, and Data recorder if present.

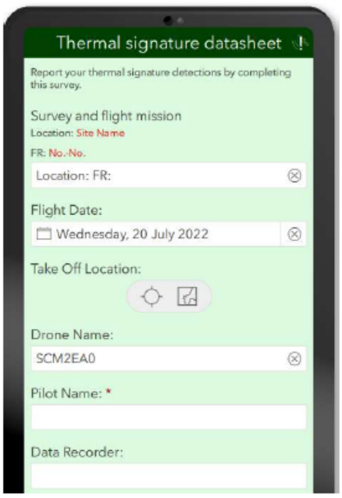

Figure 3. Mobile apps such as Survey123 allow pilots to enter data digitally while flying the drone, allowing data to be collated consistently and in near real-time.

Validating thermal detections

Koala surveys using drones followed methods previously developed by Beranek et al. (2021) and Witt et al. (2021). Two modifications in methodology were made for this study, the first involved drone validation. When an animal was detected during a nocturnal survey, and it was practical to do so, the drone would descend from 65m to an elevation that allowed for an unambiguous view of the animal (Figure 4) while remaining at least 20 meters from any native animal. As koalas are relatively slow-moving and show no negative interactions with drones, they are readily identifiable if a clear view is possible.

The second modification was designed to allow ground validation of highly mobile gliders. Ground teams with spotlights were tasked to follow the drone's path immediately after the drone. The drone's airspeed was reduced from 8m/s to 4m/s to allow the ground teams to follow the drone as closely as possible behind it.

Pilots manually assign the likelihood of thermal detection to the target species. Likelihood assignments were:

1. Certain: unambiguous imagery of the target species (Figure 4),
2. High: can identify to a species level with high likelihood, but this is based on the pilot's interpretation of thermal characteristics, behaviour, and shape,
3. Moderate: can distinguish between species groups (possum vs. glider, macropod vs. wombat) but cannot definitively label with a species,
4. Low: Thermal bloom is obscured or indistinct. There is no movement, so animal behaviour cannot be used to help identify species. Can differentiate strata (ground, arboreal, aerial) but may not be living (warm rock, termite mound, foliage).

Figure 4. To validate the species identification each drone descend from 65m to an altitude that allowed for an unambiguous view of the target species, in this case, a koala.

Estimating density

Density, the number of animals per unit area, is a complex parameter to measure by census or estimation. Arboreal mammals are cryptic, actively avoid human observers, and can occur at low density.

Drones potentially offer a new survey tool to estimate density, mainly because of their capacity to survey large habitat areas in relatively short periods. Thermal imagery reveals animals often obscured by camouflage or vegetation. These attributes help overcome the constraints of limited sampling effort and reduced detection that often limit density estimates obtained from cryptic or low-density animals.

There are various analytical techniques that can estimate or model animal occupancy and abundance, including distance sampling, capture-recapture models, occupancy modelling, n-mixture and binomial mixture models. Techniques like kernel density estimation or generalized additive models (GAMs) can also be employed for density surface modelling. Spatially explicit models often integrate environmental variables (e.g., habitat type, vegetation cover, topography) to predict spatial variation in animal density across a landscape.

Development of spatially explicit models of animal density and accounting for detection probability were outside the scope of this study. Therefore, limited inference can be made regarding koala and glider density outside the plots sampled.

A simplistic approach has been taken to estimate density as the number of detections divided by the number of surveys. This does not account for imperfect detection and represents the minimum density of animals within the plots.

Results

Kalateenee State Forest

Drone surveys were conducted in Kalateenee State Forest in July and September 2022. A total of 66 koalas were detected. Checks of the thermal blooms resulted in 37 confirmed koala sightings, leaving 29 detections identified with high confidence as koalas that could not be verified (Table 1). Figure 5 illustrates the number of koala detections at each plot for the dates surveyed.

Table 1. Survey results from Kalateenee State Forest The number of thermal blooms identified as koalas by the pilots, their likelihood, and the results of ground validation

Plot ID	Confirmed	Negative	Unconfirmed	Total koalas
1692736	3		2	5
1692739	3		2	5
1695004				0
1695006	1	1	1	2
1695008	3			3
1697274				0
1697277			2	2
1697281			1	1
1699548	1			1
1699552	2		2	4
1699555	7		2	9
1701827	1			1
1701830	2		4	6
1704097				0
1704104	1			1
1704106	1		1	2
1706377	11		1	12
1706381		1	1	1
1708655	1		5	6
1708659			3	3
1710932			2	2
Grand Total	37	2	29	66

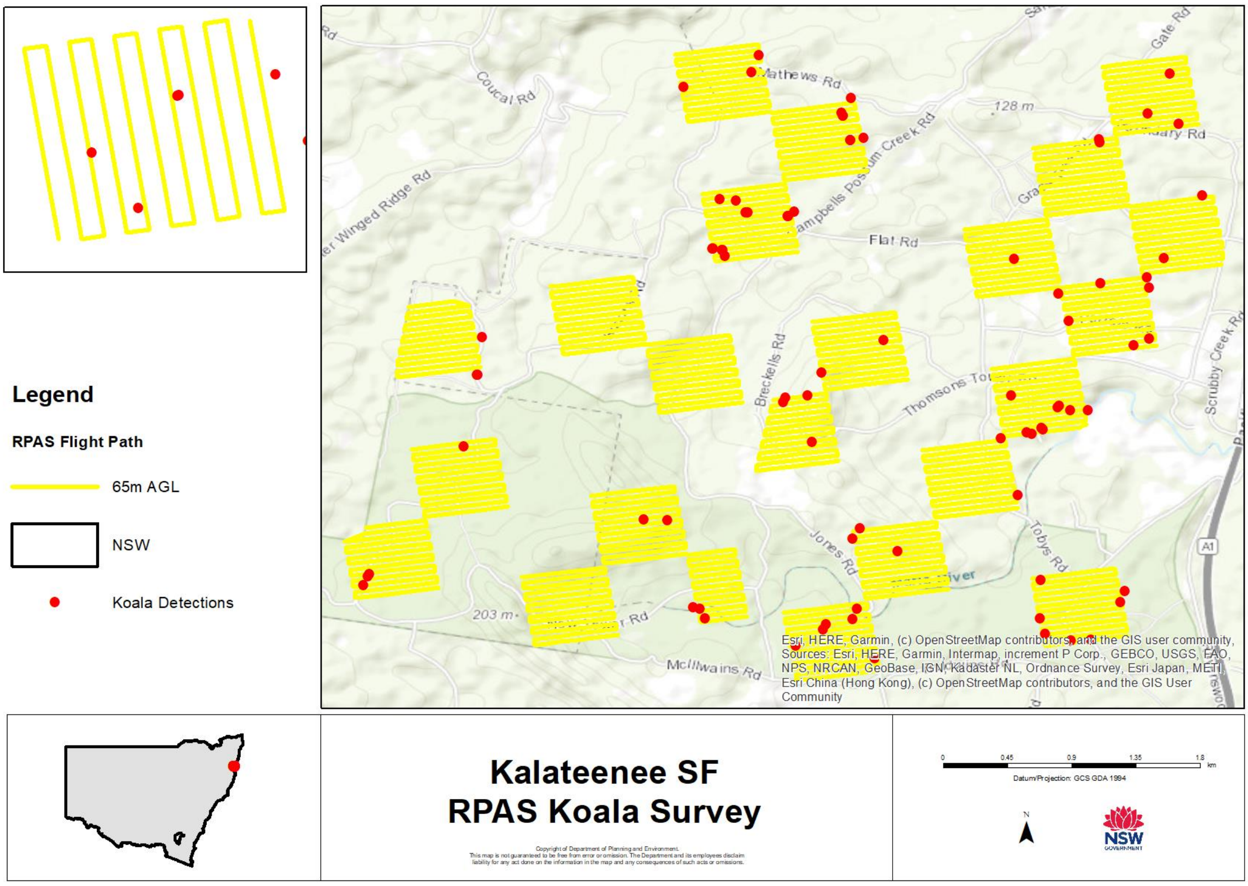

Figure 5 Drone thermal bloom/signatures (n =68) of koala detections targeted for on-ground validation during drone flights conducted in Kalateenee State Forest.

For koalas labelled as high probability detections from drone footage, 56% were able to be verified in the field by ground teams or with unambiguous drone footage (Figure 4). The remaining 29 koala detections were considered high confidence by the pilots but the animals were not accessible by ground teams. The results are summarised in Table 3. The average density of koalas in the plots surveyed is calculated as below as 0.038 koalas per hectare. This does not account for the probability of detection and so this can be considered the minimum density.

- Density of high probability koala detections: 66 koalas detected with high probability / 70 plot replicates / 25 ha per plot = 0.038 koala detections per ha

The total survey effort in Kalateenee State Forest was 70 plots of 25ha or 1,750ha.

Doyle's River State Forest

Surveys in Doyle's River took place between 26 September 2022 and 29 September 2022. In total, 12 plots of 25ha were surveyed once. Sugar gliders, greater gliders, brushtail possums, and some gliders of undetermined species were encountered. Due to the high mobility of the species, the ground teams following the drone transects could only confirm 13 greater gliders from 25 validation attempts of thermal blooms.

Table 2. The details of the pilot's certainty in species identification, and the outcome of detection validation for all glider species in the glider trial at Doyle's River State Forest. It used a ground team of 6 people to validate detections., but they were still unable to validate most detections due to the movement of gliders.

Observer certainty	Confirmed	Negative	Unvalidated	Total Potential	Other Gliders
Definite	4	0	0	4	1
High	7	8	16	23	4
Medium	0	3	8	8	5
Low	0	1	0	0	2
Undefined	0		1	1	0
Total	11	12	24	36	12

Density results are detailed in Table 3, but in summary:

- 36 Possible greater gliders detected / 12 plots / 25 ha per plot = 0.12 greater gliders detections per ha

Due to the large percentage of negative validation of detections we also calculate the minimum density of verified greater gliders.

- 11 confirmed greater gliders / 12 plots / 25 ha per plot = 0.026 greater gliders per ha

The total survey effort in Doyle's River State Forest was 12 plots of 25ha or 300ha.

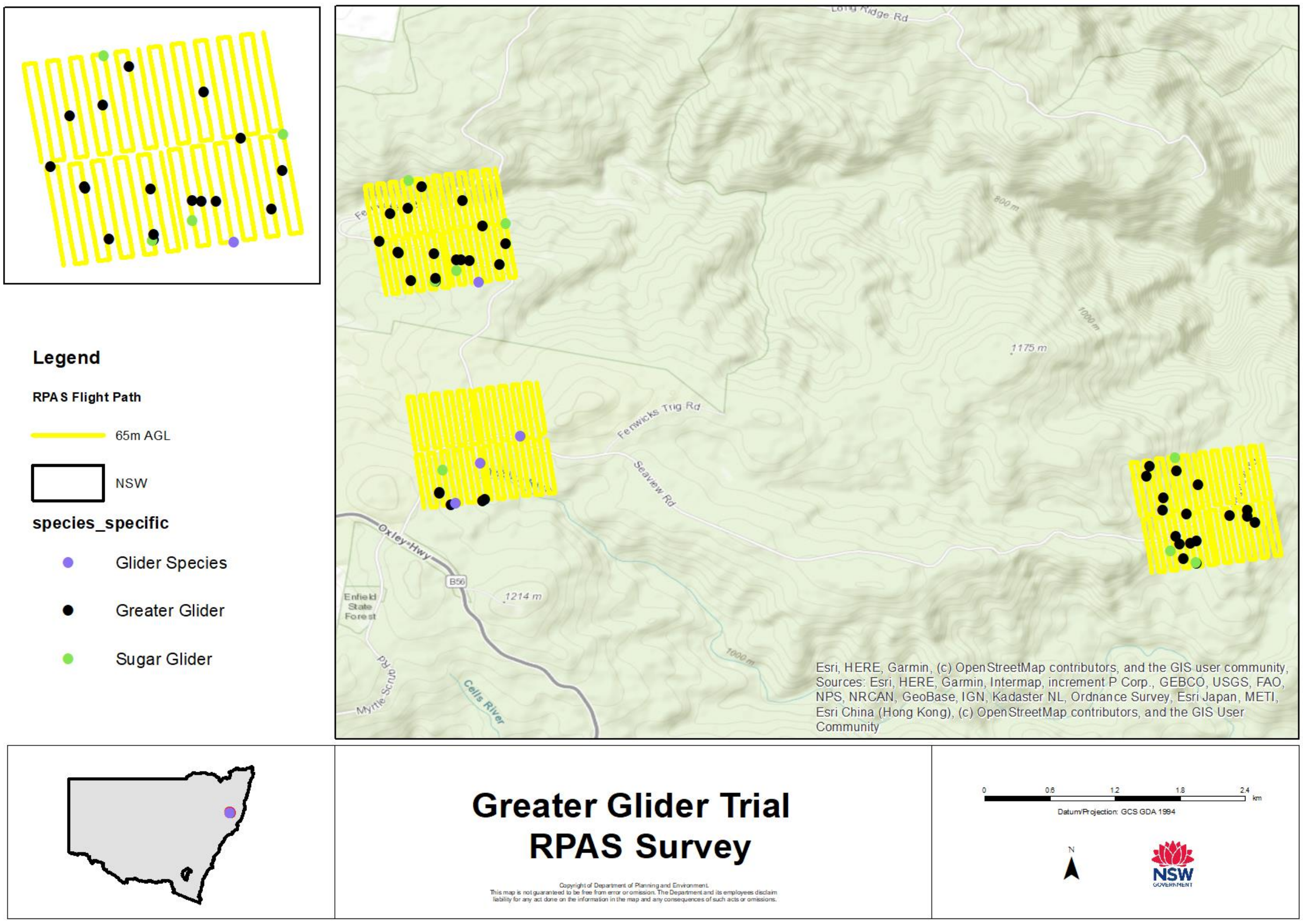

Figure 6 Drone thermal bloom/signatures (n =48) of glider detections targeted for on-ground validation during drone flights conducted in Doyle River State Forest. Only 11 greater glider detections were able to be confirmed in the field.

Table 3. The density of target animal species within the plots surveyed at Kalateenee State Forest Koalas and Doyle's River State Forest

Calculating density using drones	Kalateenee State Forest Koalas	Doyle's River State Forest Greater Gliders
Number of plots	70	12
Plot size (ha)	25	25
Number of target animals detected	66	36
Number of target animals confirmed	37	11
Density of detections (animals per ha)	0.038	0.12
Density of confirmed targets (animals per ha)	0.021	0.026
Survey effort (ha)	1,750	300
Plots per pilot per night	3	3
Number of pilots on-site	2-3	2
Number of survey days	12	5
Literature estimate of density	~0.039[1] (males only)	Na

[1] Source: Law et al., (2022) https://www.nature.com/articles/s41598-022-08013-6/figures/1

Discussion

Density

Using the raw number of animals detected will likely lead to biased population density estimates as it does not account for false negative detections (i.e., animals present but not counted) nor false positive detections (misidentified non-target species or double counting).

Repeating surveys over multiple nights at the same location, as was undertaken at Kalateenee State Forest. This provides an opportunity to model the probability of detection and model density more formally. However, the results of this analysis are outside of the scope of this study and therefore, detection probability was not accounted for in estimating density using drones. The University of Newcastle is undertaking research with the Kalateenee State Forest dataset to calculate koala occupancy and abundance and the results will be reported elsewhere.

For comparison, Law et al. (2022) estimated a density of 0.039 male koalas per ha from a song meter grid at Kalateenee State Forest. The song meter grid was not aligned with the drone surveys, and estimates were made in a different year. When the song meter estimates of koala density should be doubled to approximate the male and female population density (0.039 * 2 = 0.078). This figure is higher than the estimates of density based on drone surveys in Kalateenee State Forest (0.038). Note that the song meter density estimates were also supported by scat collection and genotyping in the study area (Gonsalves et al. unpubl. data).

Drone based validation with spotlights

Since these surveys were completed, the NSW Wildlife Drone Hub has altered the list of drones it recommends to include DJI's Matrice M30T, Mavic 3T, and Matrice M300. Each of these drones can be fitted with a powerful spotlight (2500-7,000 lumens) that is synchronised with the sensor.

Drones fitted with spotlights conduct each survey with the light off, using the thermal sensor to detect anomalies. Once a thermal bloom or anomaly is detected, the drone's autonomous mission is paused and flown manually to the bloom's location. Once overhead, the spotlight is activated. Each of the listed drones feature an optical zoom (x10 – x16) that collects RGB colour data. Imagery collected with the high-quality optical zoom generates photos and video as if collected in daylight.

This setup allows the drone to validate every thermal detection with high certainty without descending and without a ground team to verify the detections. This is particularly effective with koalas. More mobile species, like gliders, will move to avoid the light, but they are usually observed with enough detail to differentiate species.

Most pilots trained by the NSW Wildlife Drone Hub have an ecology background so they can differentiate glider species from the imagery collected, removing the need for a ground team to verify the species. We recommend subject matter experts, like animal ecologists, be trained in the use of drones, rather than relying on drone or aviation specialists.

Cost

Cost modelling for using drones to survey koalas at a landscape scale has been published elsewhere (Howell L. et al., 2022). It estimated that the cost of survey is approximately AU$3.84 per hectare excluding start-up costs such as licencing and hardware. The modelling assumes drones, training, and licensing costs at the outset to be more than AU$50,000.

The cost modelling (Howell L. et al., 2022) suggested that RPAS thermal imaging requires the lowest survey effort to detect koalas within the range of publicly available koala population densities (~0.006 - 18 koalas ha) and would provide long-term cost reductions across longitudinal monitoring programs. Note that acoustic song meters and other survey techniques were not considered in this study.

Survey costs per hectare can be calculated based on known costs per day for vehicles, travel and accommodation, salary or contractor fees and travel time (Table 4). The costs will vary with survey design. For example, for the surveys conducted for this study we would expect each pilot to conduct at least 3 x 25ha plots per night and so a team of two pilots can survey 150ha per night, with each plot nominally repeated 3 times.

Table 4 assumes a standard cost of $100/hr for personnel time. Please adjust cost estimates by altering the hourly rate where required. A standard drone team is comprised of two pilots operating simultaneously with a shared vehicle. We assume that drones take 2-hrs to survey a 25-ha site, and that three surveys can be completed in one night per pilot. Accommodation, food and travel costs are calculated daily. Accommodation is assumed to be $80.00 per person/8-hr workday, food is assumed to be $50.00 per person/8-hr workday and vehicles are assumed to be $100 per day.

Table 4. Cost estimates for RPAS koala abundance surveys

Upfront Costs	Type	RPAS Startup
Base costs (equipment startup)	Upfront	$21,732.00 (Two DJI MEA2 [$9403 each], 14 M2E batteries [$209 each])
Fauna Survey Training	Upfront	$12,000.00 ($100*40hrs*3people [two trainees and one trainer])

Upfront Costs	Type	RPAS Startup
CASA Accreditation	Upfront	$4,796.00 (Two Remotely piloted aircraft [$1999] aeronautical radio operators' certification [$399])
Total	Upfront	$38,528.00
Survey Costs	**Type**	**Staff**
Planning	Per day	$200.00 ($100*2hrs)
Personnel costs	Per day	$1600.00 ($100*8hrs*2 drone operators)
Travel costs (vehicle/food/ accommodation)	Per day	$400.00 (Accommodation: $100*2 people + food: $50*2 people + one vehicle: $100)
Total Per Day	Per day	$2,200.00

Stratified survey designs over large areas are more likely to survey one plot per day, changing the cost calculation. The Drone Hub experience is that recruiting ecologists, training them as pilots, and keeping a pool of pilots on a fixed rate is the most economical labour model. This will vary greatly based on organisational structure and survey frequency. Staffing costs depends greatly on whether internal staff or external contractors are used, and how established drone operations are within an organisation.

Training existing internal staff has a larger upfront cost (assumed $6000), than employing contractors which come pre-trained. However the relative cost comes down rapidly, as the (8 hr) day rates for a contractor (~$1100) are typically roughly double that of the hours of an internal staff member (~$625) making training internal staff more cost efficient after roughly 11 days of survey.

Pilots trained by the Drone Hub have conducted 3000 surveys across NSW at the time of writing. All drones in the inventory are still operational or have been replaced under warranty. However, each drone will depreciate to near zero value after 3-5 years. Each drone kit includes at least 10 battery changes and should be able to sustain at least 200 surveys with only minor servicing. Therefore, the Drone Hub allows for $125 of drone depreciation and insurance costs per day of operation.

Despite drones getting less expensive the cost of deploying teams in the field remains high. More pilots need to be trained to reach the economy of scale to realise the cost benefits outlined cost modelling. The NSW Wildlife Drone Hub has trained 88 ecologists to fly drones and is moving training to an online model to grow the capability further.

Standards and data

The NSW Wildlife Drone is in the processing of documenting standards to be followed by BAM assessors, other scientists, and commercial operators. Variations on these methods are operational with our partners at NPWS, the University of Newcastle and the NSW Koala Strategy (see Appendix).

To date, over 3000 surveys have taken place. The addition of the zoom lens and spotlights has increased the reliability of detections and is decreasing risk for field personnel.

It is worth noting that large volumes of thermal and colour data are collected. All detections data needs to be handled with strict protocols to avoid data loss. A data scientist and a cloud platform are required to harness these data operationally at scale. NSW Wildlife Drone Hub currently provides these services at no cost to partner organisations in exchange for data access.

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Appendix

NSW Wildlife Drone Hub

The NSW Wildlife Drone Hub enables land managers in New South Wales to survey biodiversity using drones. Our goal is to make biodiversity surveys more efficient and encourage the consistent uptake of drones to manage biodiversity.

The Drone Hub can provide specialized training that enables drones to detect wildlife and vegetation. The Drone Hub's autonomous, terrain-aware flights can be repeatedly repeated with high precision to detect trends. Data collected by drones is managed through a cloud platform that provides data management, a digital dashboard and advanced artificial intelligence (AI) analytics. The NSW Wildlife Drone Hub has surveyed over 70,000ha in NSW and conducted almost 3000 flights (Figure 7).

Through strategic partnerships and key collaborations, the Drone Hub brings scientific expertise in wildlife drone surveys in New South Wales. The Drone Hub is collaborating with the University of Newcastle, the NSW Koala Strategy, and other organizations to undertake research in the following areas:

- efficient deployment of drones at a landscape scale
- environmental, landscape, and seasonal limits of thermal drone technology
- landscape-scale koala density models
- koala detection probability for thermal drones
- Real-time artificial intelligence (AI) is used for automated thermal detection of koalas and other species.

For more information, visit the NSW Wildlife Drone Hub or contact us via email: dronehub@environment.nsw.gov.au.

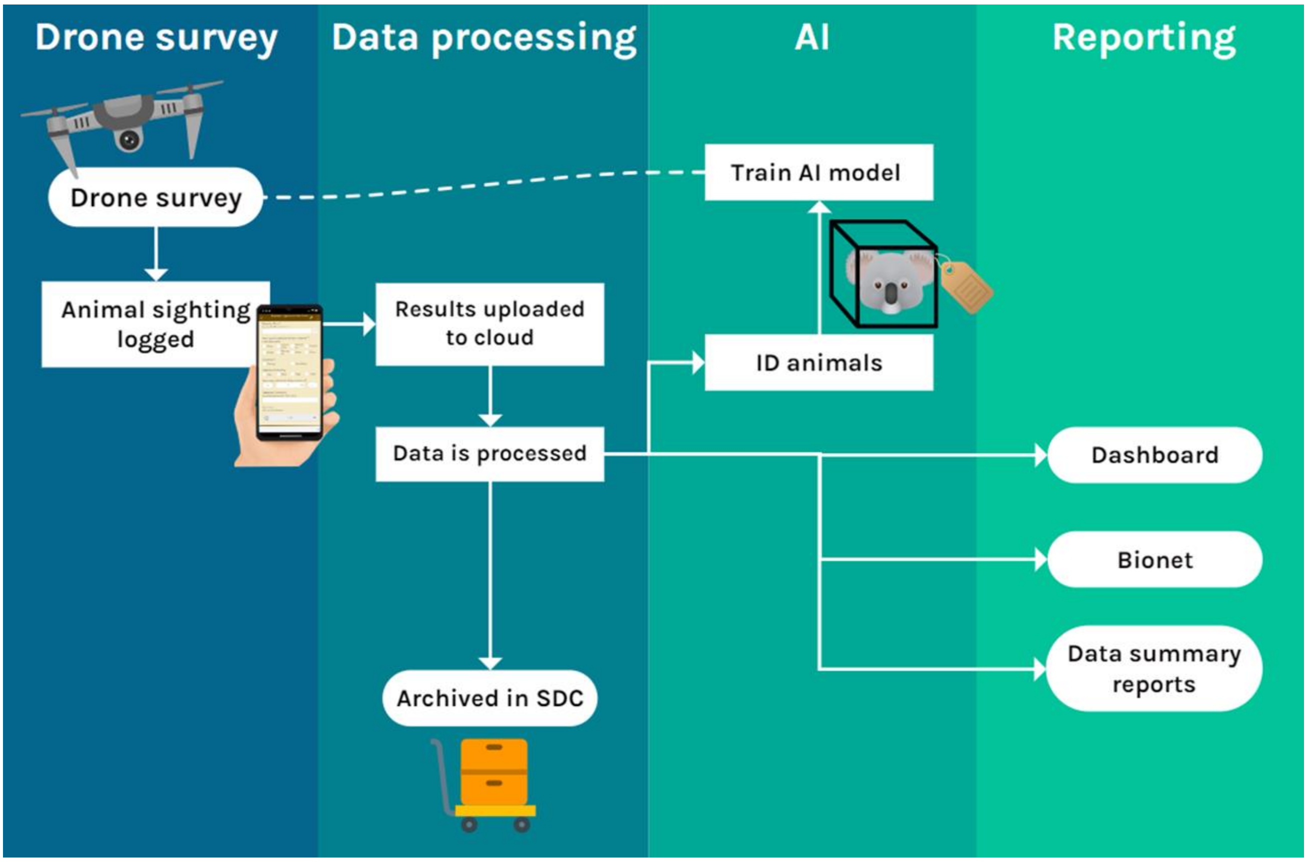

Figure 7. NSW Wildlife Drone Hub data pipeline is managed on a cloud platform. Data is available to clients in near real-time through a digital dashboard.

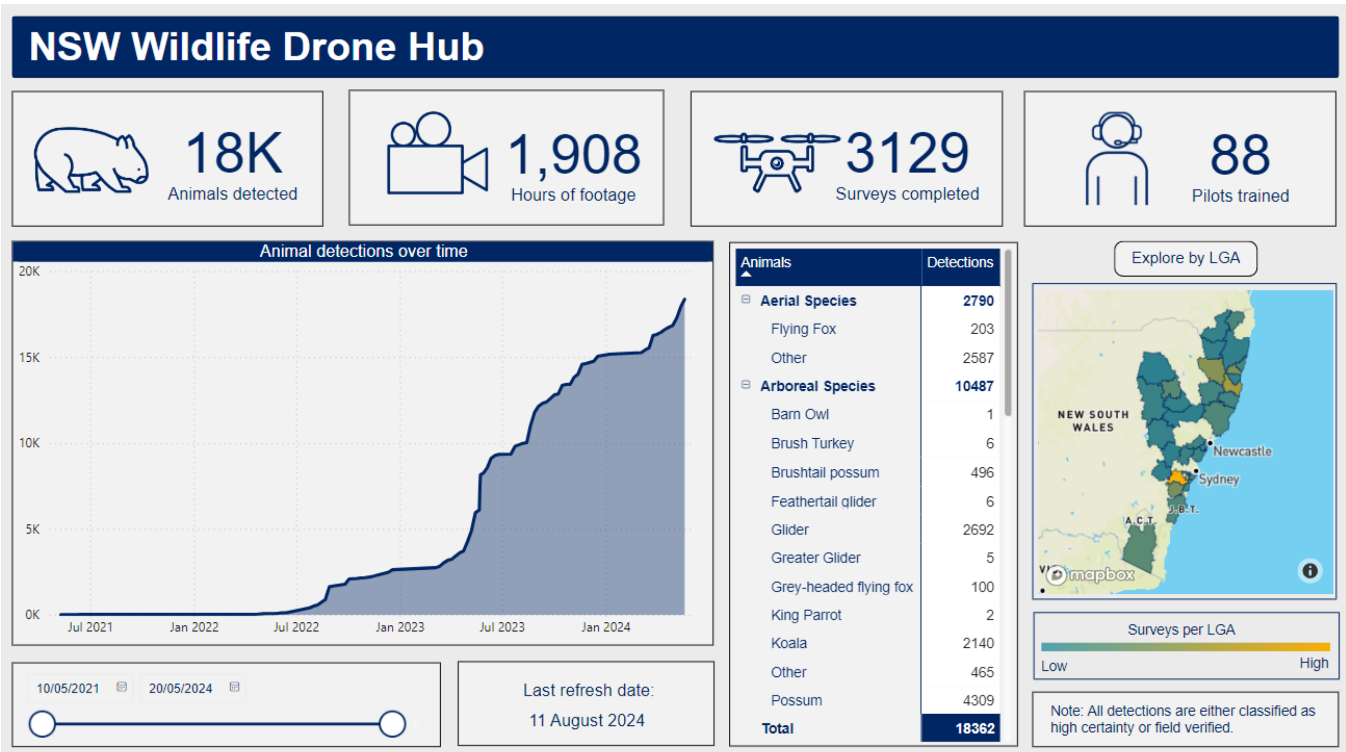

Figure 8. Pilots trained by the NSW Wildlife Drone Hub have conducted over 3000 surveys since 2022.

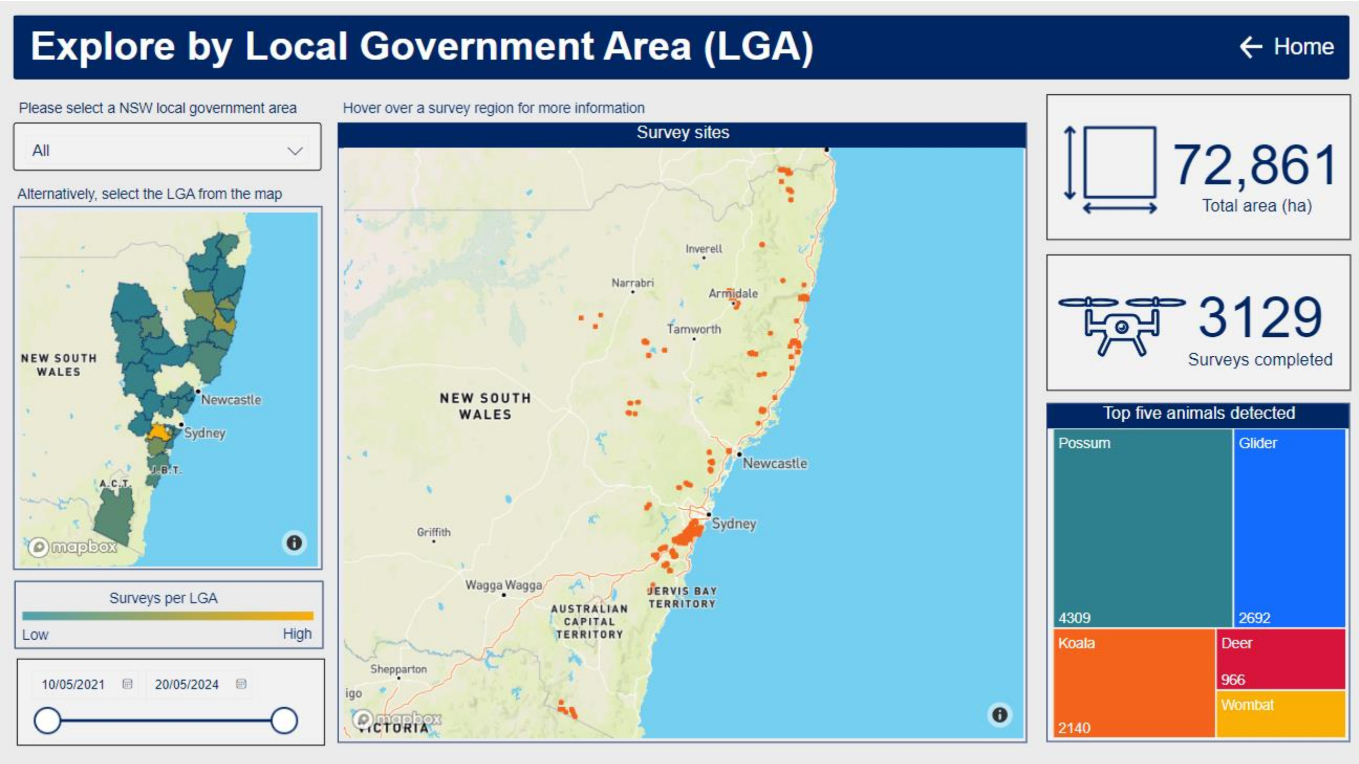

Figure 9. Pilots trained by the NSW Wildlife Drone Hub have surveyed conducted over 70,000 hectares across NSW since 2022.