NKMP Methodologies

Drones

NATIONAL KOALA MONITORING PROGRAM

The National Koala Monitoring Program (NKMP) aims to fill knowledge gaps for future Koala recovery and management efforts. CSIRO is leading the co-design of the four-year program and facilitating the roll out of NKMP with the broader Australian community. The key objectives of this monitoring program are:

- Inclusive – to enable all members of the Australian community to contribute to this national koala monitoring effort.
- Long-term – to build individual and collaborative capacity to collect robust data that can be used for evidence-based decision-making.
- Integrative - to build best-practice methods and data management systems to integrate available and new data to provide local and national insights into koala population status and trends.

The NKMP uses a wide range of approaches to monitoring koalas. This enables us to use a wealth of existing knowledge and suit our data collection methods to the specific needs of each site.

Keen to learn more? Visit National Koala Monitoring Program. Any questions or keen to find out how you can share your koala observations or data? Contact us at KoalaMonitoring@csiro.au

USING DRONES TO SURVEY FOR KOALAS

Koalas are a widespread, easily recognised, and iconic species. Despite this, finding koalas can be difficult because they often occur at low densities, and they can be remarkably difficult to see when pressed against a tree trunk or in a clump of leaves high above the ground. Fortunately, drones equipped with lightweight thermal cameras can give us a bird's eye view of the canopy and enable us to detect the koalas using their body heat (Figure 1).

We will consider two types of drone surveys.

- Active search surveys involve flying the drone manually and watching the screen for signs of koalas.
- Fully automated surveys are controlled using flight planning software and collect imagery (either still photos or videos) by flying a pre-determined path. We discuss both types of surveys in detail below.

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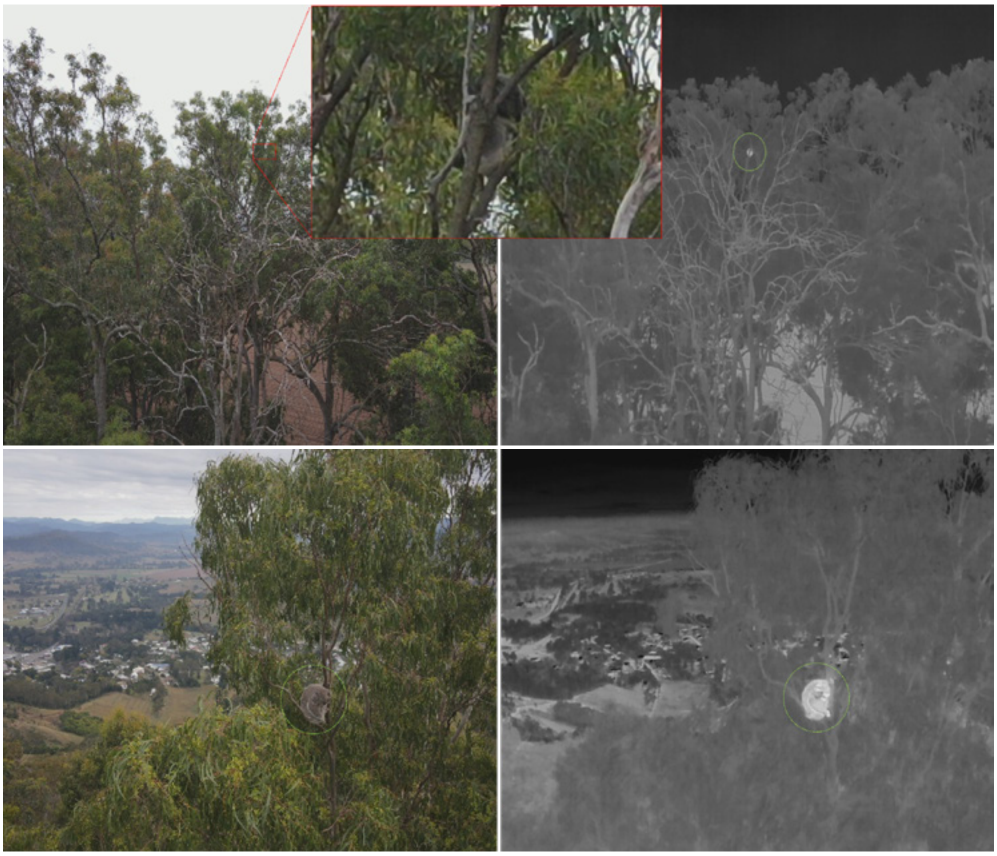

***Figure 1:* Even when koalas are easily visible in the canopy from a drone's eye view, they may not be visible from the ground. This koala was 27 m up in a tree, and not visible from the ground from any angle, even with binoculars. It was first detected with the thermal screen of the drone controller, from 120 m away.**

WHAT YOU WILL NEED

Standard equipment:

1. A colleague.
2. A GPS and enough battery power for the duration of the field work.
3. A map of the site, with salient features marked.
4. A notebook/datasheets.
5. Compass.
6. Two-way radios.
7. Appropriate field gear (PPE) such as robust shoes / boots, hat, suitable long pants and long-sleeved shirt for some scrub-bashing.

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8 Enough water and some snacks to spend a few hours away from a car, on your own.

9 Basic first aid kit.

Drone-specific requirements:

10 A drone equipped with a thermal camera.

11 Spare drone batteries.

12 Appropriate flight approvals, qualifications, safety documentation.

13 Clinometer or laser rangefinder that allows the tree canopy height to be quickly measured.

Night time equipment:

14 Good quality headlamp (optional: a handheld thermal scope).

15 Warm clothing (if needed).

Note: *The more remote the area you are working in, the more safety systems you should employ (e.g. satellite phones, personal locator beacons, safety check-in systems, extra provisions).*

THINGS TO CONSIDER WHEN PLANNING A DRONE SURVEY

Everyone involved with the flight must be aware of and adhere to all CASA regulations governing the safe operation of drones.

When planning, make sure you can maintain visual line of sight (VLOS) at all times during the flight, with the naked eye unaided by binoculars.

Remember you do not have to stay in the same position. If you need to move to maintain VLOS, do that. Some surveys can be done by walking with the drone (e.g. along a road) to maintain VLOS at all times.

Special licencing requirements are required for night flying. If flying at night, flight distances may be further than during the day because the lights of the drone are more visible at night than by day.

Maintain a minimum distance of 30m from uninvolved people. CASA regulations state that this minimum distance must be maintained at all times of the flight. Similarly, maintain a reasonable distance from nearby dwellings.

Consider the battery life of your drone and the flight time needed to complete your mission. It may be best to split a longer mission into sections. It is best to be conservative with battery power estimations as increased wind, altitude adjustments, use of accessories etc., can all drain power faster than you may have anticipated. As a rule of thumb try to have the drone returned home and ready to land by the time it reaches 30% battery life. If your drone has a return-to-home function which activates upon a set (low) battery power, or loss of signal (DJI drones

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have this), know what will happen, as it can cause the drone to behave in very dramatic ways, which could potentially lead to crashes.

It is best to practice all aspects of flying, mission planning, and pausing/resuming missions under controlled circumstances, rather than waiting until you need to conduct an actual koala survey.

FLIGHT PLANNING SOFTWARE

There is a wide range of flight planning software available for drones ranging from simple programs built into your controller to complex desktop platforms that allow for detailed control of every aspect of flight. You will need to choose the software that best suits the kind of surveys you plan to do. If you are largely running active search type surveys, pre-flight planning may be minimal. If you need to follow a specific path or produce photogrammetry products, more detailed, and automated control is required. The standard DJI-Pilot app that comes with DJI-Mavic smart controllers is sufficient for most basic flight plans including lawnmower patterns. If you need a more in-depth flight planning platform you could choose from options such as Pix4D, Drone Deploy, or UgCS but note that these are commercial products that require a paid subscription. Be sure to check that your chosen software supports your type of drone. Sometimes it takes a while for software to be updated to support newly released drone models.

Note: *If you are flying an automated flight pattern over hilly or uneven ground you need to account for the changes in elevation (Figure 2). A standard flight plan made using software like DJI-Pilot does not account for changes in elevation. It takes the elevation at the starting point and assumes that it does not change. Therefore, if you tell the drone to fly at a constant altitude of 30 m above ground, it will do so in reference to the starting point only. This could lead to a situation where your drone flies into the side of a hill or over a valley giving you an actual altitude much higher than desired. To maintain constant height above ground over changing terrain you will need to either take manual control and adjust the altitude as you go, pre-load a series of waypoints into the controller at calculated altitudes in reference to the starting point or have software that can read a digital elevation model (DEM) and automatically adjust, known as 'terrain following'. Even with a DEM the drone can't account for trees and other obstacles so always give yourself more altitude than you think you might need to avoid potential collisions. Note also, that during a "return to home" manoeuvre, the drone will fly in a straight line to get home as quickly as possible. This could potentially result in a crash.*

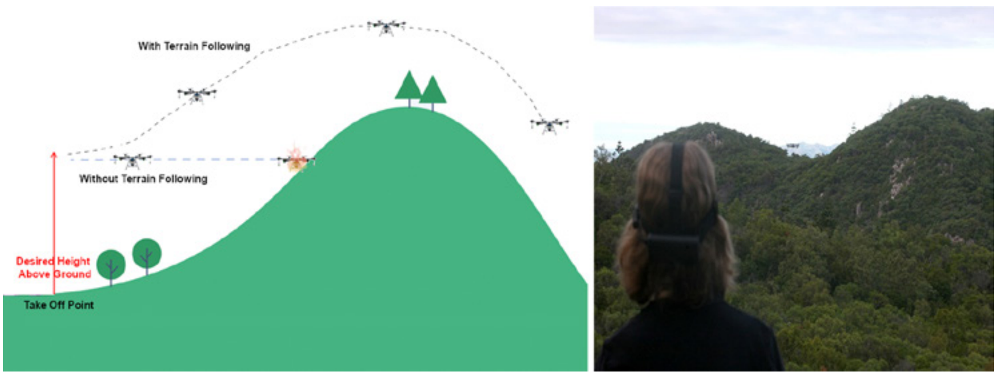

***Figure 2:* Example of a drone flying at a pre-set altitude with and without a 'terrain following' function. If the drone does not follow the terrain (either through manual control, set waypoints or using a DEM) it will maintain a constant level flight and potentially collide with the terrain.**

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PROTOCOL

For the purposes of koala surveys a drone equipped with a thermal camera is preferred as koalas can be difficult to spot through the canopy with normal cameras and will show up as “hot blobs” in thermal imagery. Thermal imagery shows you the **relative difference** in heat between an object and the background. So, for example, surveying in the middle of a hot day over sparse forest with rocky ground, will almost certainly fail to detect koalas, even if they are present, because the background is relatively hot compared to an animal’s body heat. Surveying later at night or very early in the morning will give you a cooler background and a koala’s heat signature will be much easier to spot.

In terms of how much area needs to be surveyed, this will depend on the method of analysis, whether it is a repeat survey, the amount of time available (e.g., batteries), and the nature of the landscape and terrain being surveyed. See Figure 3 below for an example.

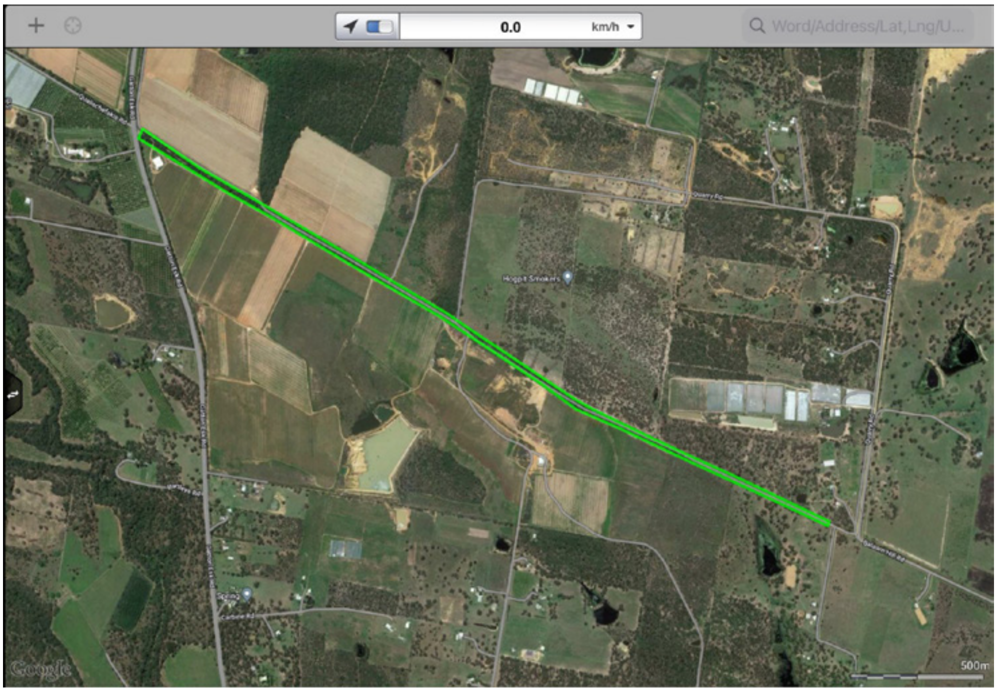

Figure 3: **The green polygon is 3 km long and between 20 and 30 m wide, running along a disused road in southeast Queensland. It is seven hectares in area. The entire polygon was surveyed using a Mavic 2 Enterprise Advanced and was completed with three batteries in a “walk with drone” survey. This included flight time involved in confirming “hot blobs” as koalas and, hovering the drone near them while attempting to see them with the naked eye and binoculars. Three koalas were observed on this strip transect, none of which were visible from the ground, even with a spotlight employed.**

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Drone surveys for koalas can be flown in two main ways:

- **Active Search** – Flying over an area (either manually or in a predefined pattern) to search using the screen on the controller, or an external screen, looking for "hot blobs" in the canopy and investigating any possible koala sightings. This method is best used if the goal is to get an accurate, real-time count of koalas in the study area and is particularly useful in low-density areas.
- **Fully Automated Search** – Flying over an area in a defined 'lawnmower' pattern with a pre-set camera angle and flight speed. This flight type is best suited for collecting imagery or video that will be analysed later either by being processed through a machine learning algorithm or to build a photogrammetry-based model of the study area.

ACTIVE SEARCHING

An active search type survey may have pre-planned elements (such as a path along a transect that the drone will follow) but is essentially a 'live' exercise where the pilot and observers watch the feed from the thermal camera and attempt to locate koalas in the field. The flight area may follow a transect that has already been walked on the ground or some other predefined area. A typical active search mission may look like this:

- Determine the area to be searched, e.g., along a pre-determined transect or a 'lawnmower' pattern over a specific block of habitat.
- If using flight planning software, program the desired route into the controller or other flight planning software (see example in Figure 4).
- If flying fully manually, plan out your route and flight parameters in advance so you can cover the desired area.

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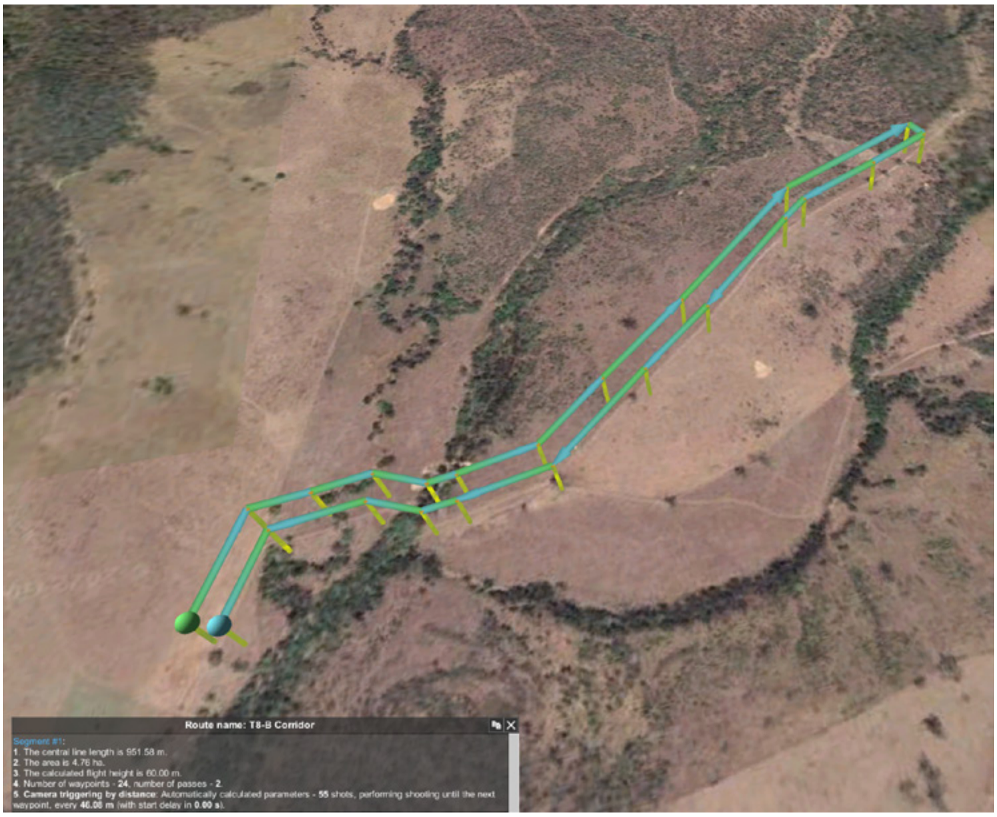

Figure 4: **Example of a pre-planned route along an existing transect. In this case, a road. The drone will fly at 60m out and back along the trail covering an area of 50m each side of the road, a total area of 4.7ha. Observers will actively search the live video feed for 'hot blobs' indicating possible koalas.**

- Set a flight altitude high enough to avoid collisions with trees. The desired flight altitude will vary with the survey environment. Typically, 45m above ground is sufficient to be able to make out koalas anywhere in the forest strata in a 35m tall forest.
- Set the camera angle to between 25 and 45 degrees down, if possible, to give the best chance of spotting koalas. The desired angle may need to be set on a site-by-site basis in order to determine the best visibility through foliage.
- Set a flight speed that is slow enough to be able to watch a smooth video feed on the controller (or external screen) with no jumpy or blurry images as the camera refreshes. 3-6 m/s is a good starting point
- Take off and begin flying along the pre-determined path.
- If the pilot or other observers see any hot blobs that could be koalas, pause the mission and take full manual control

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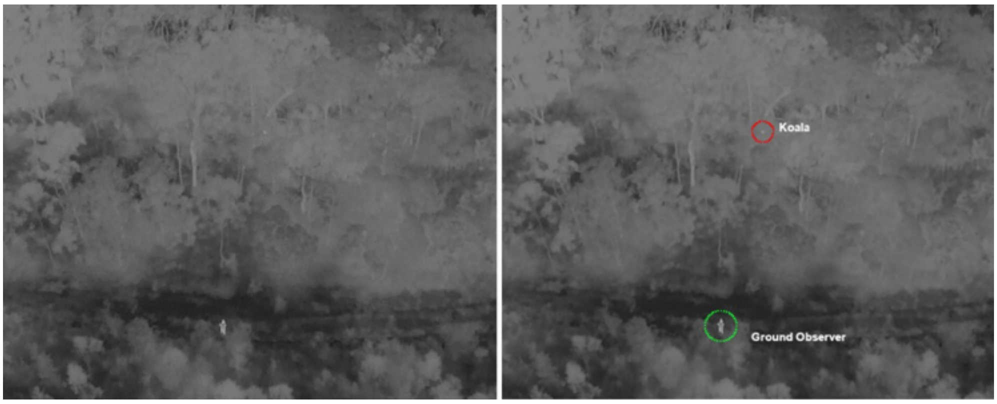

***Figure 5:* Can you spot the hot blob? This one was confirmed as a koala by the ground observer**

- Fly the drone as close to the hot blob as possible, while making sure that you don't disturb the animal. Changing the camera angle and moving up or down will help confirm that it is in a tree and not on the ground.

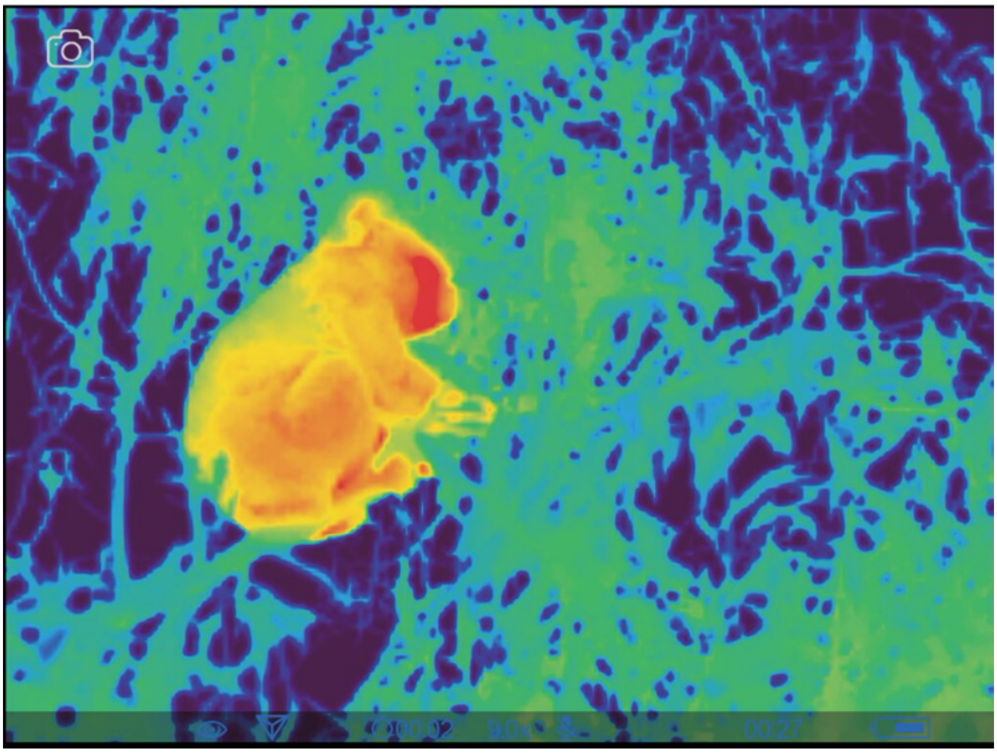

***Figure 6:* The potential koala spotted in Fig 5 above confirmed on a handheld thermal scope**

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- If there is a potential that it is a koala, fly directly over the tree and take a GPS point from the drone and as many photographs and/or videos as possible
- If possible, send a member of your ground team to that location to confirm the sighting
- If battery power allows, it may help to hover the drone over that tree until the ground team get there.
- Once the sighting has been logged, return to the pre-determined path and back to the flight.
- Continue the active search as above until the entire search area has been covered.

Recording the Data

Different drones and flight control software will provide different levels of details about the mission you have just flown. As a minimum try to record a flight log with the following information about your flight:

- Date and start time.
- Pilot.
- Site Information.
- A unique identifier label for this flight.
- Drone model and camera type.
- Altitude.
- Camera angle.
- Area covered.
- Total flight time (long multi-battery flights are treated as one flight) .
- Total number of koalas spotted on this flight.

Note: *Recording the total flight time and area covered is particularly important as this will act as a measure of survey effort and will allow for comparisons of different surveys by different users.*

If any koalas were spotted, their details can be recorded in data sheet that links to the flight log using the unique flight identifier. Here you should record a row for each sighting with the following information:

- Unique flight identifier.
- Date and time of observation.
- Latitude and longitude of koala.
- Number of koalas sighted at this location.
- Any details gathered by ground crew such as tree species, size, sex or age of koalas, health status etc.

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FULLY AUTOMATED SEARCH

In some cases, it is necessary to gather imagery using very precise, repeatable parameters such as the exact flight path, flight speed, overlap between images, altitude etc. For example, if carrying out repeated surveys in the same place, or if the goal is to produce detailed imagery that can be stitched together, or to provide consistent video footage to identify koalas automatically from the imagery. In these cases, it is best to use a fully automated flight that is planned to use the same parameters every time.

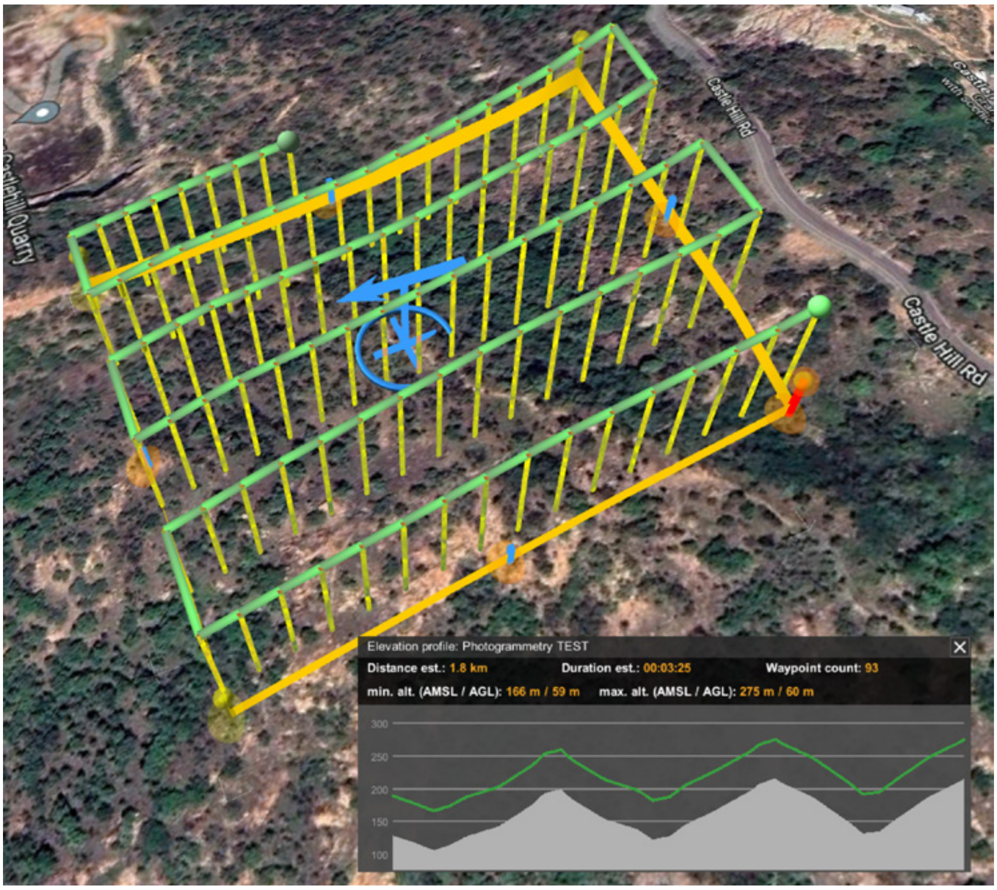

***Figure 7:* Example of a 'lawnmower' type pattern used to cover a study area. Note the elevation profile shows the drone is using terrain following to maintain a constant height above ground.**

Depending on the desired outccome, different parameter settings will be used. Regardless of whether the imagery is used in a machine learning alorithm or for photogrammetry, it is crucial for repeatability that all flights use the same set up.

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If stitching and georectification of the thermal images are required, the camera must be facing directly downwards and the amount of overlap between images needs to be very high (~70-80% overlap). For a video analysis you may need to have the camera at 45 degrees and a smaller overlap (~10%) may be used to ensure total coverage. It is important that you know what the goal of the survey is and how the data will be processed. This will allow you to set your parameters correctly.

The degree of overlap between images will have a significant effect on the time it takes to fly your mission and hence your battery usage. See Figures 8 and 9 below for examples of how different overlap changes the flight time needed. Note that the frontal overlap ratio does not have any effect on flight distance or time; it only affects the number of images taken.

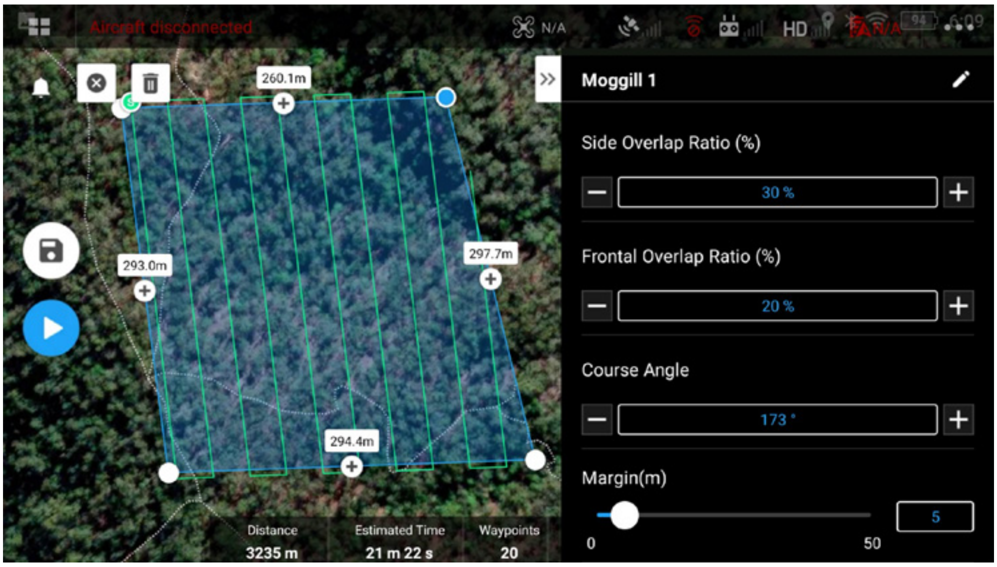

***Figure 8:* Example of a lawnmower pattern covering 0.81ha with a 30% side overlap between images. The estimated flight time here is 21min, just about at the limit of a single battery in a standard quadcopter drone.**

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***Figure 9*: The same flight as in Fig 8, covering the same area, but this time with 80% side overlap and 80% front overlap. The flight time has increased dramatically, now taking more than an hour which would require 3-4 batteries.**

As you can see from the figures above, the chosen parameters for your automated flight can drastically change the flight time. Multi-battery missions are possible but require the ability to pause the mission, fly the drone home, switch batteries, fly back to the point that the mission was paused and restart the mission from there. If the mission is covering a large area, it may be necessary to change take off locations partway through to ensure you can maintain VLOS during the entire mission. In this case it is recommended that you simply plan two separate missions and then combine the data afterwards.

A generalised outline of a fully automated flight might look like this:

- Pre-plan your flight mission considering:
  - The area to be covered
  - Desired overlap between images
  - Altitude above ground (balance spatial resolution of images with need to avoid collisions)
  - Total flight time - how many batteries will be needed?
  - Flight speed
  - Include waypoints at the beginning and end of the mission at or near the take-off/landing site
- Upload the mission to the drone

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- Take off to required altitude
- Start the mission and maintain VLOS at all times
- Monitor the controller display for battery life or any malfunctions
- If battery power drops to 30%, pause the mission, return home, change battery and resume the mission from the pause point
- Once the mission is complete, land the drone and download the imagery.

SOME EXTRA TIPS

Be clear about what data you are collecting and how it will be used later. Keep in mind that you are collecting imagery and other data for analysis after you land. If you are clear about what that purpose is, it will help you to fly the drone in a manner that collects the best possible data for your needs.

Using a whiteboard or notebook, write out the basic flight details (date, location, pilot, etc.) and use the drone to take a photo of this before take-off and after landing each flight. This will help keep imagery organised by bookending the files related to each flight as well as adding an extra layer of identification to the imagery.

When flying a lawnmower pattern, pay attention to the orientation of the pattern. If the study area is irregular in shape, rotating the pattern might give you a more efficient flight path.

Some pilots recommend orienting a lawnmower pattern such that the drone is moving away from the observer and then back towards them rather than moving across their field of view from side to side. This means that on every pass the pilot and observer get a good look at the drone, and it approaches the home location regularly in case anything goes wrong. If moving side to side in relation to the observer, the drone could spend a lot of time moving farther and farther away from the observers leaving it at its most distant around the time when batteries are likely to be running low.

You need more batteries than you think. On a typical survey it is not uncommon to burn through 5 – 10 batteries. Bring more than you think you need and have a mobile charging unit that can be used in the field.

If undertaking night flights, bring extra lights to illuminate the take-off and landing area making it easier for the drone to land safely.

ACKNOWLEDGEMENTS

The NKMP acknowledges the 120+ workshop participants who reviewed a range of koala survey and approaches as part of the 2023 National Koala Conference.