21. The use of LiDAR to determine the presence of Malleefowl mounds

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Abstract

The determination of the presence and number of Malleefowl *Leipoa ocellata* utilising prescribed or predicted habitat is often a prerequisite in development approval processes, typically prior to disturbance and often as part of ongoing monitoring. Given the vast extent of potential preferred Malleefowl habitat across Australia, and the species' ecology, it is difficult to estimate population size based on bird counts. The occurrence of Malleefowl mounds is typically used as a proxy for the bird's occurrence. However, finding Malleefowl mounds can be time consuming, labour intensive, expensive and may not be practical in large areas. To provide greater certainty and transparency in locating Malleefowl mounds, Umwelt has developed a process to identify 'candidate mounds' using LiDAR data and to rank them according to their likelihood of being 'actual mounds'. Because LiDAR can penetrate through vegetation, mounds that are covered or masked by vegetation can also be readily identified. The detection process developed combines rapid analysis of extremely large data sets using Umwelt's in-house software *Anditi*, with the field knowledge and expertise of our experienced ecologists. Where available, aerial photography is incorporated into the software to provide additional information on habitat and landscape context for the area surrounding candidate mounds. The combination of computer analysis and ecological expertise allows candidate mounds to be quickly virtually accessed in 3D on computer, and then GPS locations recorded for subsequent ground-truthing in the field. This provides repeatability and transferability of the Malleefowl survey process through providing a 3D image of ground and vegetation surrounding each site, while significantly reducing the costs and time required for field surveys.

Introduction

The Malleefowl *Leipoa ocellata* is one of three members of Megapodiidae in Australia and is the most southerly distributed in the country. Its distributional range in semi-arid and arid habitats differs from that of other extant megapodes that occupy damp forests. The incubation methods typically used by megapodes (mound building) are not conducive to these dry regions. The Malleefowl has, therefore, developed a highly sophisticated and elaborate technique of incubation of its eggs. Malleefowl eggs are laid in a mound, comprising an inner core of leaf-litter buried under a thick layer of sand. The decomposing effects of the leaf litter generate heat for the developing eggs, aided by the use of solar heat later in the season. Malleefowl tend to the mound frequently during the incubation period, ensuring a constant temperature within the egg chamber. They manage this by adjusting the level of cover over the egg chamber particularly later in the season when they rely more on solar energy. Thus, a thinner layer of sand lets more heat in during the day and a greater layer of sand retains the heat within the mound overnight.

Similar to other megapodes, the chicks are superprecocial, which render them vulnerable to predation. The ecology and distributional range of the Malleefowl have exposed it to major threats including predation, clearing of preferred habitat with associated fragmentation and isolation, and altered fire regimes. These, together with other threats and its declining status, have resulted in the development of a National Recovery Plan for Malleefowl *Leipoa ocellata* (Benshemesh 2007) for this iconic species.

Conservation Status

The conservation status of the Malleefowl in Australia is presented in Table 1 below.

Table 1. Conservation status of Malleefowl *Leipoa ocellata* in Australia.

Jurisdiction	Status	Legislation
Commonwealth	Vulnerable	*Environment Protection and Biodiversity Conservation Act 1999*
State/Territory		
Northern Territory	Critically Endangered	*Territory Parks and Wildlife Conservation Act 2000*
New South Wales	Endangered	*Threatened Species Conservation Act 1995*
South Australia	Vulnerable	*National Parks and Wildlife Act 1972*
Victoria	Threatened	*Flora and Fauna Guarantee Act 1988*
Western Australia	Vulnerable	*Wildlife Conservation Act 1950*
Non-statutory NGO		
IUCN	Vulnerable	IUCN Red List of Threatened Species
BirdLife Australia	Vulnerable	The Action Plan for Australian Birds 2010

Distribution

Malleefowl have declined substantially throughout Australia since European settlement. While this species was formerly widespread across Australia, its range appears to have contracted significantly. An indicative map of the present distribution of Malleefowl is presented in Figure 1 (Department of the Environment 2014). More prescribed distributional maps are presented in Figure 2 (BirdLife International and NatureServe 2014), Figure 3 (ALA 2014 Records), Figure 4 (OZCAM (2014) distributional map) and Figure 5 (NatureMap distribution of records from Western Australia (Department of Parks and Wildlife (DPaW) 2014)).

Figure 1. Indicative map of the present distribution of Malleefowl (Department of the Environment 2014).

Figure 2. Present range of Malleefowl (BirdLife International and NatureServe 2014).

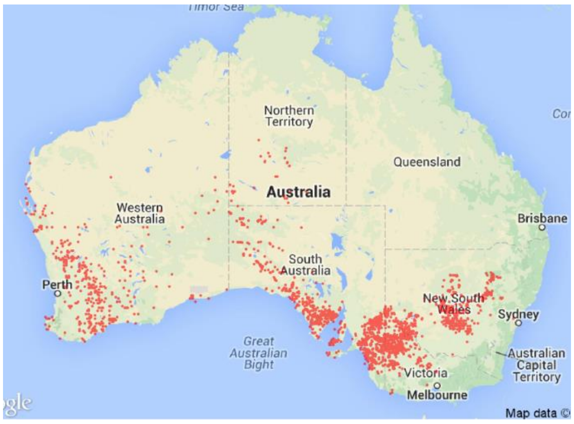

Figure 3. Records of Malleefowl from ALA (2014).

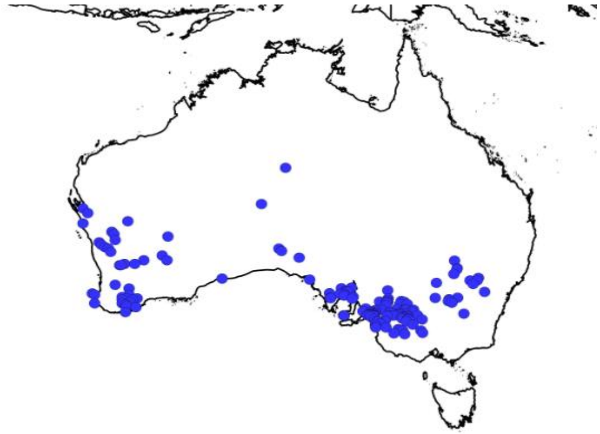

Figure 4. Records of Malleefowl from OZCAM (2014).

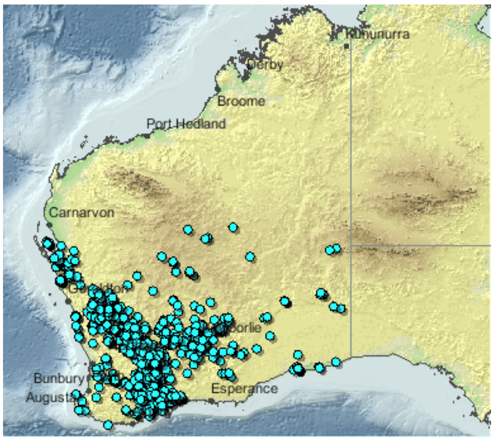

Figure 5. Records of Malleefowl from NatureMap (DPaW 2014).

Monitoring

The determination of the presence and number of Malleefowl is often a prerequisite in development approval processes, typically prior to disturbance and often as part of ongoing monitoring. Monitoring requirements often include or relate to:

- baseline population information;
- a requirement as part of approval applications for disturbances such as clearing of native vegetation, mining projects etc.;
- annual monitoring to determine mound usage/activity and population trends;
- effectiveness of management actions;
- recovery plan actions; and
- fulfilment of conditions from statutory authorities (e.g. Ministerial Statements, project approval conditions etc.).

There are conventionally three methods of monitoring, which include:

- sighting of individuals;
- tracking for signs (tracks, feathers, scats); and
- counting mounds.

While the sighting of birds is the most conclusive evidence of their presence, the second method provides an indication that one or more birds have occurred in the area recently, and the third method determines if Malleefowl have used the area to establish a breeding mound.

A further distinction when counting mounds is determining if they are 'active' (breeding occurring in the current season), recently used or old (moderately old, old or very old). Comments on each of the three methods of monitoring are provided in Table 2.

Table 2. Malleefowl monitoring methods.

Method	Comments
Sighting of individuals	• Elusive • Cryptic • Not a reliable method of determining population numbers or densities
Tracking for signs (tracks, feathers, scats)	• Suitable substrate required • Wind and rain obscure tracks • Not a reliable method of determining population numbers or densities
Counting mounds	• Best indicator of population

While counting of mounds provides the best indicator of habitat use by Malleefowl, a variety of techniques for counting mounds have been developed. Comments on each of the techniques are provided in Table 3.

Table 3. Malleefowl mound counting techniques.

Method	Comments
Aerial searches using helicopters	• Expensive and may not identify all mounds
High resolution aerial imaging	• Need open ground • Problematic due to shadows • Miss mounds covered with and hidden by vegetation
Thermal imaging	• Only effective when mounds are active • Expensive
Plot searches/monitoring grids/sampling approach for tracks	• Only in suitable substrates • Not suitable following wind or rain
Walking	• Time consuming • Expensive • Labour intensive • Annual checks of known mounds likely to miss new mounds
LiDAR	• Most efficient and reliable method of mound detection over large and/or remote areas

LiDAR and its Application to Malleefowl

What is LiDAR?

Light Detection and Ranging (LiDAR), also known as 3D laser scanning, was conceived in the 1960s for submarine detection from aircraft. Most airborne LiDAR systems are made up of the LiDAR sensor, a GPS receiver, an inertial measurement unit (IMU) and onboard computer and data storage devices.

The LiDAR system pulses a laser beam towards the ground, typically from a fixed-winged aircraft but also from helicopters and more recently UAVs. The beam is scanned from side to side as the aircraft flies over the survey area, measuring up to 200,000 points per second. When the laser beam hits an object, it is reflected back to the sensor on the aircraft. The time interval between the pulse leaving the aircraft and its return to the LiDAR sensor is measured and stored. This data is then processed and the time intervals are converted and corrected in accordance with the other instruments (GPS coordinated, IMU etc.) to describe points in space where the object was detected. The LiDAR sensor collects a huge amount of data and a single survey can easily generate millions of points totalling several terabytes.

There are two broad categories of LiDAR systems based on the method of recording signals:
- discrete-return systems (Figure 6); and
- full waveform systems (Lefsky *et al.* 2002) (Figure 7).

Figure 6. Discrete return system.

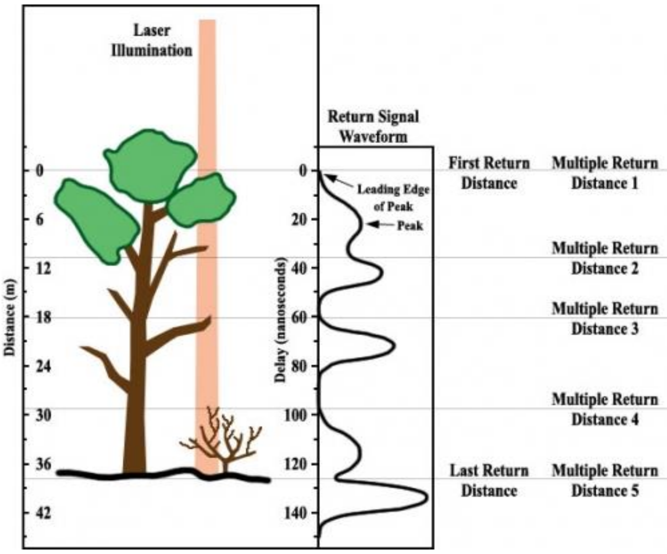

Figure 7. Full waveform system.

The discrete-return system only records a few (e.g. one to four) reflections per transmitted pulse, while the full wave-form system digitizes the entire return waveform at very high sampling frequencies (e.g. 1 GHz) and hence it is able to record up to around 80 samples per transmitted pulse. This allows significantly more data per pulse to be recorded and that provides a superior 3D representation of the subject area including canopy, sub-canopy structures, other infrastructure, ground cover and ground surface.

Aircraft typically fly along the length of the survey area, make precise turn-arounds, and fly the length in the opposite direction, with each tract called a swathe. These swathes are repeated until all parts of the survey area have been covered. The precision of the flight path is important; any overlaps between swathes can be accounted for during the analysis of the data.

To be able to detect near-ground features such as Malleefowl mounds, the LiDAR data has to be of sufficient density and accuracy, and then accurately classified as to whether it is ground, elevated ground or vegetation.

Formerly, the analysis of the large amount of data generated from a single survey was a time and energy consuming, laborious process requiring many hours and many computers. However, the Geospatial team at Umwelt has developed software, known as *Anditi* that has the ability to efficiently apply appropriate series of algorithms to the data that processes the information and provides detailed results in a timely manner.

The Problem

While the threats to Malleefowl have been recognised, the trend in Malleefowl populations generally is poorly known. The home range of the Malleefowl can be extensive ranging from over one to several kilometres in the course of a year (Benshemesh 2007). During the breeding season males spend most of the time in the vicinity of their mounds. Notwithstanding this, the elusiveness and great distances do not lend themselves to accurately determine the numbers of Malleefowl in any one area.
Given the difficulties in finding and counting individual birds, the occurrence of Malleefowl mounds has been typically used as a proxy for the bird's occurrence. However, finding Malleefowl mounds can be time consuming, labour intensive, expensive and may not be practical in large, remote areas. Typically, a line approach is used in which a number of suitably qualified surveyors stand in a line equidistant from each other and walk along pre-determined tracks searching for Malleefowl mounds. The distance between people is determined by the density of the vegetation with distances as close as five metres apart in dense vegetation, and greater distance in sparse vegetation. Similar to swathes, tracks are walked along the length of the survey area until the entire area has been surveyed. However, as tabled above (Table 3), a most efficient method of reliably detecting Malleefowl mounds over large and/or remote areas is with the use of LiDAR.

Umwelt's Solution

Umwelt ecologists and our geospatial team realised that the extensive datasets being collected or able to be collected in LiDAR runs would include information about Malleefowl mounds – they just needed to be able to discern mound 'signatures' within the billions of LiDAR points returned in a typical survey. To give a sense of how difficult this is, there are typically two million to five million LiDAR points in each 1 km^2 of data. A Malleefowl mound is typically represented by just ten points to twenty-five points and there may be vegetation covering the mound.

Umwelt has completed searches for potential Malleefowl mounds using LiDAR data in areas up to 1,000 km^2. Manually examining billions of LiDAR points in such a large area would not be feasible, so Umwelt has developed software to search through the data for mounds, even those covered by vegetation. An algorithm ranks mound-like objects, with the most likely mounds then presented visually to the user one by one, to enable suitably experienced ecologists to determine if the candidate mound is a Malleefowl mound. This software Umwelt has called *Anditi.*

Locations of the identified mounds are then placed in a GPS so that they can be visited in the field to confirm whether they are actually mounds or not. This approach provides substantial time saving when searching for Malleefowl mounds within large areas.

Umwelt's algorithm does not discriminate between recently active mounds and those that were last used several years ago. However, the software provides information on the height and diameter of each mound, plus an indication of whether a central 'pit' was present when the LiDAR was collected. The central 'pit' may be indicative of an active mound that has been opened up intermittently late in the season to allow solar energy to heat the eggs, an old mound where the central core is collapsing or a mound that has been predated and where the eggs have been excavated leaving a central 'pit'. This emphasises the importance of having experienced ecologists ground-truthing LiDAR results of potential mounds.

LiDAR data should ideally have at least two points per square metre to find Malleefowl mounds, although studies in heavily vegetated areas will benefit from higher resolutions to ensure the ground has been defined adequately by the laser. With good data, both megamounds and mounds as low as 0.1 m in height have been observed in LiDAR data.

The following figures provide examples of the various mound age classifications:
Figure 8 represents an active mound with both litter and many scratchings present;
Figure 9 represents an active mound within an old mound that has collapsed;
Figure 10 represents and old mound with a central pit and partially covered with vegetation; and
Figure 11 represents and old domed mound covered in vegetation with no central pit.

Figure 8. Active mound.

Figure 9. Active mound within collapsed mound.

Figure 10. Very old mound covered in vegetation with central pit.

Figure 11. Very old mound covered in vegetation.

Case Studies

In the case studies presented in this paper, LiDAR data had already been collected by the client and was presented to Umwelt for analysis. After initial receipt of the data, a range of quality control and data verification checks were conducted as the first stage of working with the data. The steps used to process spatial data included:

- data verification:
  - preliminary check of the data;
  - backup copy of the data;
  - load data into databases;
  - check vertical alignment of LiDAR swathes;
  - check horizontal alignment of images with LiDAR;
- correct data alignment where necessary;
- generate landform from ground points;
- undertake project-specific analysis from LiDAR and aerial imagery to identify potential Malleefowl mounds based on general profile characteristics of Malleefowl mounds;
- engage Umwelt's experienced ecologists to assist with the identification of potential mounds; and
- develop list of GPS coordinates for ground-truthing of candidate mounds.

Case study 1

Umwelt's first Malleefowl survey using LiDAR was conducted in 2011/2012 at a site approximately 175 kilometres (km) north-west of Kalgoorlie in the Yilgarn Craton, Western Australia.

The LiDAR data provided to Umwelt for analysis had already been collected at two points per square metre over 80,000 hectare (ha). Analysis of the data identified 102 potential candidate mounds (see Figure 12 for example of potential mound). Ground-truthing of these candidate mounds confirmed 99 out of the 102 mounds were actually Malleefowl mounds, giving a 97 per cent (%) chance that each candidate target was a Malleefowl mound.

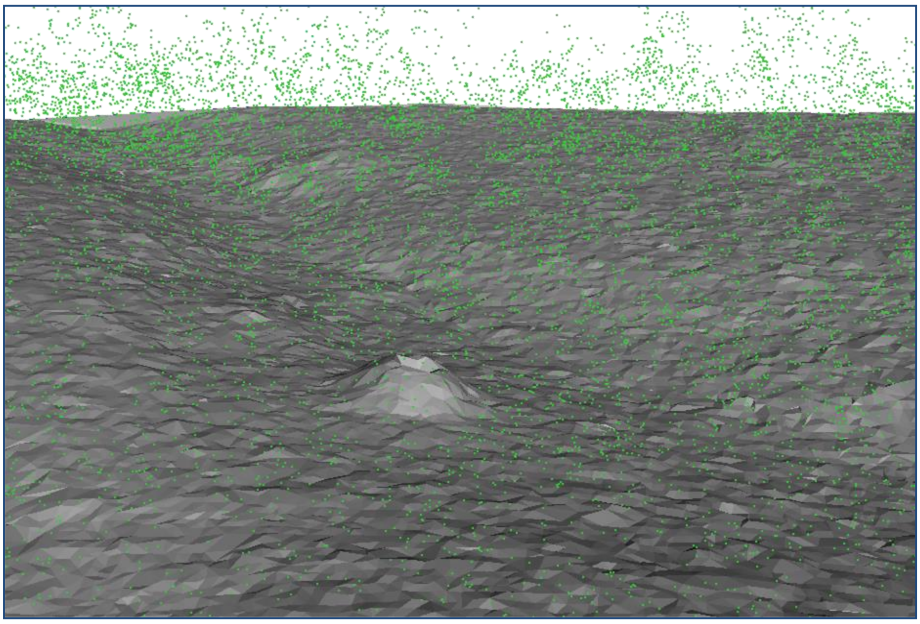

Figure 12. Analysis of LiDAR data depicting a potential Malleefowl mound surrounded by varying levels of vegetation.

Case study 2

A second case study was undertaken in 2012 at a mine site approximately 100 kilometres north-east of Southern Cross in the Yilgarn region of Western Australia. The Malleefowl survey was conducted to comply with a Ministerial Condition that required an annual search for Malleefowl mounds within a buffer area of 12,000 ha.

The LiDAR dataset provided to Umwelt for analysis was flown in April 2012 and had 0.5 points per square metre. A total of 144 potential mounds were identified from the dataset, with only 21 potential mounds within the survey area. Of these 21 potential mounds, 15 were confirmed to be Malleefowl mounds and six were either circular rocky outcrops (n = 3) (Figure 13) or circular areas of vegetation (n = 3) (Figure 14). Collectively this can be interpreted as a 71.4 % success rate of LiDAR data analysis.

Figure 13. Example of circular granite outcrop.

Figure 14. Example of circle of vegetation.

The lower success rate in identifying potential mounds in this study highlights the difference in the number of points fired per square metre, with more points (two points per square metre) providing greater accuracy (97%) compared with fewer points (0.5 points per square metre) resulting in lower success in identifying Malleefowl mounds (71.4%).

It is recognised that more points per square metre will provide more information from the data, with a concomitant higher success rate.

Summary of Specific and General Benefits

Specific benefits

Specific benefits of using LiDAR to assist in the identification of Malleefowl mounds include, but are not limited to, the following:

- The ability to survey large areas in remote locations before a far reduced team of ecologists (one or two) target ground-truthing of potential Malleefowl mounds in those locations.
- Reduced costs (time and money) of ecologists on the ground.
- Reduced on-site impacts.
- The ability to accurately determine ground levels and changes.
- The ability of LiDAR to ‘see’ through vegetation covering mounds.

LiDAR cannot replace the skills and experience of ecologists in the assessment of Malleefowl mounds. However, adding LiDAR to ecologists’ toolbox of ecological and technical competencies will enable more targeted work for ecologists to be undertaken with much more accurate results. While the initial startup/analysis costs may be a disincentive in some cases, the results and medium to long term outcomes of the use of LiDAR will negate these. Further, the associated general benefits of capturing LiDAR may far outweigh these initial mobilisation and analyses costs.

General benefits

Raw and interpreted LiDAR data that are captured as part of Malleefowl mound detection campaigns can also be used for a range of other purposes. These can include:

- generating high resolution digital terrain models;
- contour information;
- vegetation structure and cover;
- forestry and silvicultural purposes including percentile tree counts and stem measurement, and identifying certain tree species/genera such as Cypress Pine and introduced pines;
- identifying vegetation communities including Threatened and Priority Ecological Communities;
- monitoring rehabilitation progress;
- generation of continuous topography for general/specific analyses;
- monitoring landform changes including stockpile and embankment details;
- erosion and deposition volumes;
- wide-area surveys for features;
- characterising site features to choose sites for environmental surveys;
- information on the built environment such as roads, buildings and other infrastructure;
- line of sight analysis to determine visual impacts;
- high resolution data for environmental modelling (air, noise, flood); and
- carbon accounting, fuel load assessment.

Conclusion

Given the conservation status of the Malleefowl and the uncertainty of determining population trends, any advance of the time-consuming, labour intensive line approach of surveying for Malleefowl mounds would be a welcome advance for ecologists. The use of LiDAR to detect Malleefowl mounds in remote areas and across vast landscapes has proven to be an innovative and feasible technique. The information gained through this technique can be used by ecologists to better predict Malleefowl populations and, thereby, make better informed decisions when reviewing management options for this iconic species.

The Authors

From digging up trapdoor spiders to detailed mapping large swathes of vegetation, and many more talents within the ecological spectrum, Vi and Travis collectively have nearly 50 years of experience.

Vi has principally worked in faunal ecology throughout Western Australia both in research and in the field, and has also worked briefly in New South Wales. Vi has conducted all Levels of fauna surveys in accordance with Guidelines and Position Statements issued by the Western Australian Environment Protection Authority and the Western Australian Department of Parks and Wildlife under the Western Australian *Environmental Protection Act* 1986 and *Wildlife Conservation Act* 1950, and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999.

Specifically, Vi has walked many, many miles conducting line approach Malleefowl surveys, worked together with the geospatial team fine-tuning the search criteria within the algorithm and conducted the first ground-truthing exercises, providing valuable feed-back to enhance the *Anditi*™ system.

Travis is Umwelt's Practice Leader Ecology, a role in which he conducts and oversees ecological studies and assessments across Australia by Umwelt's team of regionally-based Ecologists. His background is in the mapping and surveying of vegetation communities across bioregional landscapes, including vegetation community statistical classification and threatened ecological community management. Travis also has a background in threatened fauna surveying and management. In his current role he is primarily focussed on ecological impact assessments, biodiversity offsetting and ecological management plan preparation and monitoring, including major project approvals under state/territory and Commonwealth legislation.

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