# Comparative Assessment of Malleefowl Mound Search Techniques

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## Introduction

This study compares the efficacy and cost of different techniques for detecting malleefowl nesting mounds in native vegetation in an area of the Mt Gibson Ranges in Western Australia. The techniques trialled were ground searches, high resolution aerial imagery, and light and detection ranging (LiDAR) technology.

Malleefowl (*Leipoa ocellata*) are a conservation significant species of Megapodiidae (mound building avifauna).[1] This species is currently listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and is identified as requiring special protection under the relevant legislation in each Australian state and territory in which it occurs.[2] Malleefowl are widespread across Australia and occur in all states except Queensland and Tasmania.[3]

Malleefowl are an elusive species, widely recognised as being difficult to detect and measure using standard fauna trapping and monitoring techniques.[4] Established monitoring practice for this species is to use breeding density, measured by the number of active nesting mounds, to assess population health.[5]

Malleefowl build a large mound of sand and/or rocks and pebbles, depending upon material availability, and leaf litter. Mounds vary in diameter, generally between 3 to 5 metres.[6] Mounds are generally circular at the base but the height and profile vary depending upon factors such as the frequency of use, temporal interval since last use, and for active mounds, the stage in the mound building cycle and weather conditions, in particular temperature.

A key aspect of any malleefowl monitoring program is the initial identification of mounds. Malleefowl exhibit a preference for re-using existing mounds rather than creating new mounds so re-searching the survey area is only undertaken every 5 – 10 years.[7] If mounds are not detected in the initial surveys, future variations in data associated with birds moving to undetected mounds may be incorrectly interpreted as a decline in breeding activity and conversely, birds moving from an undetected mound to a known mound may be misinterpreted as population recovery.

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[1] Benshemesh, J. (2007) *National Recovery Plan for Malleefowl. Department for Environment and Heritage*, South Australia.
[2] *Threatened Species Conservation Act 1995* (NSW); *Territory Parks and Wildlife Conservation Act 2000* (NT); *National Parks and Wildlife Act 1972* (SA); *Flora and Fauna Guarantee Act 1988* (Vic); *Wildlife Conservation Act 1950* (WA).
[3] National Malleefowl Recovery Team, 2016, *Malleefowl Facts* <http://www.nationalmalleefowl.com.au/malleefowl-facts.html>.
[4] Hopkins, Liz (eds) *National Manual for the Malleefowl Monitoring System*, National Heritage Trust.
[5] Ibid.
[6] Benshemesh, above n 1.
[7] Hopkins, above n 4.

Initial searches and any subsequent re-searches of a study area are often the most costly part of the monitoring project as the ongoing monitoring component involves accessing only the known mounds. Thompson et al (2015) presented a comparison of the effectiveness and cost efficiency of on ground searches relative to high resolution aerial imagery in the Mt Gibson area of Western Australia. This current study supplements this work by comparing these techniques to the use of light and detection ranging technology (LiDAR).

## Project Site

The study site is approximately 1,200 ha of malleefowl habitat in the vicinity of the Mt Gibson ranges in Western Australia. This area is a sub set of a broader area that has been extensively searched for malleefowl mounds as part of the environmental impact assessment process and ongoing monitoring requirements for the Mt Gibson Iron Ore Mine and Infrastructure Project. Extension Hill Pty Ltd (EHPL) and Mount Gibson Mining Limited (MGM) are joint proponents of this Project. MGM provided funding and assistance for both this study and the previous photogrammetry study.[8]

Fauna assessments undertaken at the site recorded four broad fauna habitats in the study area, specifically sand plains, eucalypt woodlands, slopes and iron stone ridges.[9] The study site spans fifteen vegetation associations, predominantly thicket communities, but also including two mallee communities, two woodland communities and one heath community.

## Survey Techniques

### *On Ground Searches*

On ground searches involve physical grid searches of an area by a team of people, spaced between 5 m and 20 m apart, depending upon the density of the vegetation which impacts upon the visibility of mounds. Mounds are identified and marked with GPS. Initial on ground searches were conducted over a broad area incorporating the study site in March 2004, September 2004 and January 2005. Additional on ground searches which included a section of the study site were undertaken in December 2013, June 2014 and May 2015. There were 45 mounds identified in the 2004-2005 searches and an additional 7 in the subsequent 2013-2015 searches (this excludes mounds that were recorded in the initial survey but could not be located in subsequent monitoring surveys).

The cost of this technique may be influenced by a number of factors including the density of the vegetation, weather conditions, and personnel related factors. Thompson et al (2015) calculated the cost of this technique as $21.36/ha for this particular site.

### *High Resolution Aerial Imagery*

The aerial photography technique is described by Thompson et al (2015) as follows

> *In October 2013, aerial photography images of an area of 7,014 ha were captured using a Microsoft Ultracam D largeformat camera mounted in a Shrike Aero Commander 500. A forward overlap of 70% and a side overlap of 60% were used to provide stereo images suitable for searching on a computer. Cross strips were added to the flight paths to aid in determining vertical accuracy. The quality of the images enabled a ground sample*

[8] Thompson, S., et al (2015) Using high-definition aerial photography to search in 3D for malleefowl mounds is a cost-effective alternative to ground searches. *Pacific Conservation Biology*. 21(3):208-213.
[9] ATA Environmental (2005) *Fauna Assessment Mount Gibson*, Report No 2004/51.

*distance of 4 cm. This aerial photography was then post processed to provide images able to be searched on a computer and then loaded and examined in DTMaster (INPHO). Stereo images were examined using NVIDIA 3D Vision Glasses.*[10]

The images were systematically examined by moving 40 m strips of imagery vertically up or down a 23" monitor and identifying any mound like features. The features were classified as 'confident' or 'potential' mounds depending upon the examiners level of surety of each feature.

Each recorded feature was then inspected on the ground. Of the 75 'confident' locations checked within the current study area, 72 were confirmed to be malleefowl mounds. Of the 34 'potential' locations checked in the current study area, 23 were confirmed to be malleefowl mounds.

The cost of the survey using aerial imagery was calculated to be $9.55/ha, however it is noted that due to mobilisation costs of the aircraft, economies of scale would apply and this technique may not be as cost effective over smaller areas.[11]

### *LiDAR*

LiDAR (Light Detection and Ranging) is a surveying method that measures distance to a feature such as the ground or a tree from a known point by illuminating the feature with pulsed laser light and measuring the reflected pulses with a sensor. The LiDAR pulses are emitted by a scanner. In this case a high accuracy terrestrial LiDAR scanner (Reigl VZ2000) that was attached to a fixed wing aircraft. The aircraft was flown over the survey area allowing the ground surface and vegetation features to be accurately recorded. The LiDAR coverage for this project achieved a density of returned pulses from the ground surface of approximately 6-7 pts/$m^2$. In addition to the ground, LiDAR pulses reflected back off trees and shrubs creating a rich 3D point cloud model of the surface and vegetation.

LiDAR was flown in December 2015. In all, 10 separate sites covering a combined survey area of 12,000 ha in the vicinity of Lake Moore in WA were flown as part of the LiDAR survey.

This study focusses on the results for the 1200 ha Mt Gibson which was one of the ten sites flown. The 3D point cloud generated by the LiDAR survey of the Mt Gibson site contained over 150 million points. Each of these points was then analysed and classified as either ground, vegetation (low, medium or high), road or water using an automated computer-based classification program developed by Anditi. Following classification of the LiDAR point cloud, those points classified as ground were then used to create a Digital Elevation Model (DEM) of the site. The DEM generated was then analysed using a computer based series of algorithms developed by Anditi to detect ground surface features that have the potential to be a malleefowl mound.

Each of the potential malleefowl mound features (or Blobs) detected were then automatically ranked using a series of geometric indicators as how closely they represented a 'typical' malleefowl mound (dome shaped, round, with or without a depression in the middle). Each potential mound was then given a 'Blobsum' score which totalled up how well the mound scored against series of indicators used.

As we all know, malleefowl mounds have a wide range of sizes shapes and configurations at the time of construction and post construction. The shape depends on what resources were available at the time of construction (geological and biological), what part of the breeding cycle the mound was in at the time of survey, whether it is a mound that has been used for a long time, period since the mound was last used or erosion processes that the mound has been subject to since it was last used and

[10] Thompson, above n 8.
[11] Thompson, above n 8.

whether other biological processes such as foxes, dingos and humans may have interfered with the mound impacting on its shape.

Needless to say, it is very hard to define what a ‘typical’ shape is or what a ‘typical range of mound shapes’ might be and even harder to develop algorithmic rules that categorically determine whether a ‘Blob’ is a mound or not. This process is further complicated by the representativeness and accuracy of the data used to generate the DEM that is used to determine the location of ‘Blobs’ and whether they might be malleefowl mounds or not. In an attempt to address this challenge, each of the potential malleefowl mounds are inspected virtually (i.e. a 3D visualisation of the mound is generated and examined on a computer) by a human who then ranks the Blob or potential mound on a scale of 1 to 4 with 1 being high potential and 4 being low. This process is also not an exact science and could be greatly improved by developing a more comprehensive set of ‘rules’ as to what is a mound and what isn’t.

The assessment of the DEM generated from the LiDAR of the Mount Gibson site identified a total of 1,781 features (Blobs). They were rated on a scale of 1-4, where 1 is considered to be the perfect mound shape, 2 is great mound shape but with uncertainties (likely to be active or active in the last few years), 3 and 4 are not likely to be valid mound candidates. The features were compared against the known mound database by Mt Gibson Mining staff and the category 1, 2 and 3 features that did not match any known mounds were inspected on the ground. In undertaking a comparison of the results, features located within 15m of the database coordinates of a known mound were considered to be referring to that particular mound. Of the 173 category 1, 2 and 3 features recorded, 86 were actually mounds. An additional 10 known mounds were identified by LiDAR as category 4 features. The remaining 1,598 category 4 features were not inspected.

The known location of 110 mounds within the survey area was provided to Umwelt in March 2016 in order to refine the algorithm for detecting mounds. A revised dataset containing 121 category 1 features, 145 category 2 features and 329 category 3 features was created. The category 1 features in the revised dataset were assessed and inspected. Eighty-eight of these were mounds, with four being newly recorded. A desktop assessment of the category 2 and 3 features was undertaken to compare to known mound locations. Eight category 2 and twelve category 3 features coincided with known mounds, however three of the category 3 records overlapped category 1 and 2 records.

The study area formed a small component of the broader 12000 ha LiDAR survey covering 10 sites which reduced the overall cost. The cost per hectare was approximately $7.51/ha. This was made up of:

- $2.59/ha for the capture and processing of LiDAR and imagery;
- $0.40/ha for the classification of the 3D LiDAR point cloud, generation of the DEM, analysis and identification of potential malleefowl mounds and virtual inspection and ranking (1 to 4) of the mounds;
- $4.52/ha being the estimated cost of field checking the 173 potential malleefowl mounds (categories 1 to 3). The source of the data does not affect the process of ground truthing. To enable a cost comparison, the cost of ground truthing the potential mounds was calculated by adjusting the $2.85/ha calculated by Thompson et al (2015) to reflect the increased number of mounds. It is assumed that category 4 mounds will not be checked.

As with aerial imagery, economies of scale apply to reduce the flight cost per hectare when a larger area is flown.

## Results

### *Initial LiDAR results*

Approximately 70% of the known mounds were located using the initial LiDAR technology. Of these, 34% were classified as category 1, 14% as category 2, 12% as category 3, 9% as category 4. Four of the category 1 features were disregarded as they appeared to refer to the same mound as 3 other category 1 features. Two category 1 features coincided with 'confident' features identified in the photogrammetry survey which were investigated and found not to be mounds. The remaining 7 category 1 features, 9 category 2 features and 85 category 3 features were ground truthed. Twenty additional mounds were recorded (7 category 1, 6 category 2 and 7 category 3).

**Table 1 Summary of Initial Lidar Results**

| | | Category | | | | Total |
|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | |
| **No. of features** | | 51 | 24 | 98 | 1608 | 1781 |
| **No. confirmed mounds** | **Previously recorded** | 38 | 15 | 13 | 10 | 76 |
| | **New** | 7 | 6 | 7 | 0 | 20 |
| **No. confirmed not mounds** | | 2 | 3 | 78 | 0 | 83 |
| **No. of double ups** | | 4 | 0 | 0 | 0 | 4 |
| **No. not checked** | | 0 | 0 | 0 | 1598 | 1598 |
| **Known active mounds** | | 2 | 2 | 3 | 3 | 10 |
| **New recently active mounds** | | 1 | 2 | 1 | 0 | 4 |

The sheer volume of the category 4 features makes ground truthing impractical. Mapping indicates that they are concentrated mainly in and around disturbed areas, such as tracks, the mine site waste rock landform and the mine pit, implying they may be the result of earthworks rather than malleefowl. Further qualitative examination indicates however that disregarding all category 4 features may prove detrimental, since 3 of the 10 mounds that were recorded as 'active' in monitoring conducted in November 2015 were classified as category 4. Disregarding this category of mounds would have resulted in underestimating the breeding population by at least 30%.

### *Revised LiDAR Results*

The revised algorithm identified approximately 78% of the now 130 known mounds in the survey area. The category 1 features were ground truthed and an additional four new mounds were identified. A further 454 category 2 and 3 features were not ground truthed so there is potential that additional mounds may have been located but were not confirmed. The practicality and value of ground truthing large numbers of features is discussed above. Disregarding category 2 and 3 features would have resulted in missing at least 17 mounds.

**Table 2 Summary of Revised Lidar Results**

| | | Category | | | Total |
|---|---|---|---|---|---|
| | | **1** | **2** | **3** | |
| **No. of features** | | 121 | 145 | 329 | 595 |
| **No. confirmed mounds** | **Previously recorded** | 84 | 8 | 9 | 101 |
| | **New** | 4 | - | - | 4 |
| **No. confirmed not mounds** | | 25 | - | - | 25 |
| **No. of double ups** | | 8 | - | 3 | 11 |
| **No. not checked** | | - | 137 | 317 | 454 |

### *Technique comparison*

In total there were 52 mounds identified by on ground searches, 9 of which were not found by any other means. Ninety four mounds were located using aerial imagery, 14 of which were not located by any other means. LiDAR detected 96 mounds during the initial survey, 20 of which were not located by any other means, and at least 105 mounds using the refined algorithm, 4 of which were not located by any other means. This may be an underestimate as the category 4 features were not ground truthed due to the impracticality of checking 1,608 features. For comparative purposes the initial LiDAR results are used as most sites will not have an extensive existing mound database to enable algorithm refinement.

**Table 3 Comparison of Results for Different Techniques**

| | Ground Search | Aerial Imagery C | Aerial Imagery P | LiDAR 1 | LiDAR 2 | LiDAR 3 | LiDAR 4 |
|---|---|---|---|---|---|---|---|
| Ground Search | 52 | 36 | 1 | 13 | 5 | 7 | 5 |
| Aerial Imagery C | | 72 | | 32 | 12 | 10 | 3 |
| Aerial Imagery P | | | 23 | 6 | 3 | 2 | 4 |
| LiDAR 1 | | 13 | 32 | 45 | | | |
| LiDAR 2 | | 5 | 12 | | 21 | | |
| LiDAR 3 | | 7 | 10 | | | 20 | |
| LiDAR 4 | | 5 | 3 | | | | 10* |

* Since ground truthing of the category 4 LiDAR results was not undertaken this may be an underestimate.

## Discussion

There are a number of factors to be considered in selecting the most appropriate method for a particular site. Table 4 summarises the key aspects of each technique. These techniques were tested over an area which included large patches of dense vegetation and areas with artificial disturbance including tracks and a waste rock landform. It is anticipated that results may vary in other locations and other vegetation types.

The density of the vegetation makes ground searches difficult and can impact on the accuracy of these searches. The presence of artificial disturbances yielded a large number of false detections from the LiDAR technique. The number of category 4 features identified is likely to be lower in less disturbed areas.

Consideration must be given to the financial cost of a technique, as well as the accuracy of the technique in regards to the number of mounds identified, and the number and quality of the mounds missed.

For the circumstances of this study, the LiDAR technique was the most cost efficient, partly due to the fact that the area was included in a broader project over which the mobilisation costs were dispersed. This analysis excludes the category 4 features. If the category 4 features are included, the cost of ground truthing would result in a significantly higher cost and LiDAR would no longer be the most cost efficient technique. By comparison, assuming the costs of collecting the aerial data (LiDAR or photo imagery) are equivalent for a particular area, the cost of LiDAR is lower due to the reduced time and labour required for analysis, however where there are significantly more false detections, this cost benefit would be lost due to the higher ground truthing cost.

It is however noted that excluding the category 4 LiDAR features would have meant failing to detect 10 known mounds, 3 of which had been recently active. It is also noted however that LiDAR detected the highest number of mounds that were not detected by any other technique.

Initial on ground searching recorded the lowest number of mounds. It is acknowledged that there may have been new mounds created between these surveys which were 8-10 years apart, however it is unlikely that all of the mounds discovered by the aerial techniques were not present during the initial ground truthing survey. Some of these mounds appeared old and were disused.

Ground searching is a labour intensive technique and requires a high level of planning and coordination to address fatigue and safety related issues associated with traversing the bush. Depending upon the density of the surrounding vegetation and the number of people involved, there is also potential for detrimental impacts on the surrounding flora and fauna resulting from this high intensity human traffic, often in reasonably pristine native vegetation.

The advantage of this technique is that once the mounds are identified and measured during the on ground searches, further ground truthing is not required.

The fatigue and safety issues identified for on ground surveys would also apply to the ground truthing component of the aerial techniques although to a lesser extent. Since ground truthing involves accessing specific locations rather than traversing the entire site, less time is spent in the field, so the period of exposure to field risks is proportionally reduced.

The image analysis component of the aerial imagery process requires a high level of focus, as mounds could easily be missed if the person conducting the analysis becomes fatigued or distracted.

**Table 4 Key Aspects Summary**

| | **Ground truthing** | **Aerial imagery** | **LiDAR*** |
|---|---|---|---|
| **Number of mounds in study area** | 130 | 130 | 130 |
| **Year of survey** | 2005 | 2013 | 2015 |
| **Mounds detected** | 52 | 95 | 86 (original);<br>≥105 (revised algorithm)** |
| **False detections** | Nil | 14 | 87 (original);<br>≥25 (revised algorithm)** |
| **Mounds detected only by this technique** | 9 | 14 | 20 (original);<br>≥4 (revised algorithm)** |
| **Estimated cost ($/ha)** | 21.36 | 9.55 | 7.51 |
| **Conditions in which this technique would be favourable** | Easily trafficable, open vegetation with high visibility;<br>Small areas;<br>Availability of large numbers of volunteers. | High level of disturbance/artificial features to be distinguished from mounds;<br>Larger areas. | Densely vegetated natural areas;<br>Larger areas. |
| **Positive features** | Can be cost effective for small areas if volunteers are available. | Economies of scale cost benefits;<br>Ability to re-analyse data set;<br>Accuracy;<br>Low number of false identifications. | Economies of scale cost benefits;<br>Unbiased analysis;<br>Ability to re-analyse data set;<br>Accuracy;<br>Analysis is computerised and cost effective. |
| **Negative features** | Labour intensive;<br>Costly on large scales;<br>Less accurate. | Potential for 'human error' in analysis.<br>Analysis requires long hours of concentration. | High number of false identifications. |

* Category 4 LiDAR features have been excluded from this analysis.

** 454 category 2 and 3 LiDAR features identified by the revised algorithm were not checked.

## References


ATA Environmental (2005) *Fauna Assessment Mount Gibson*, Report No 2004/51.

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