# 24. Comparison of three survey techniques for locating Malleefowl mounds

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***Abstract***

Accurate and cost effective location of nesting mounds underpins most monitoring and management activities for the nationally threatened Malleefowl. Mounds are often concealed in dense vegetation that is difficult to walk through and survey methodically. We compared mound detection rates in three 1 sq. km grids of mallee woodland on north-eastern Eyre Peninsula in South Australia.

Grids were surveyed using three different techniques: 1) two spotters in a helicopter, 2) by a team of people walking a grid on the ground, and 3) by canopy piercing Airborne LiDAR (Light Detection and Ranging) laser scanning from an aircraft. The relative cost-effectiveness of each survey technique was compared, along with the percentage of false positive and false negative records of purported Malleefowl mounds. Commentary is provided on the most appropriate and cost-effective search techniques for different purposes and suggestions for how to improve the precision and cost-effectiveness of LiDAR surveys for Malleefowl mounds.

***Introduction***

Malleefowl (*Leipoa ocellata*) are nationally threatened birds that inhabit much of the semiarid and southern arid regions of Australia. Due to their listing under the national *Environment Protection and Biodiversity Conservation Act* 1999, Malleefowl typically feature in biological survey, monitoring and environmental offset programs for industrial development throughout their potential range. Malleefowl construct large mounds, typically four to six metres in diameter and up to 90cm high in which they incubate their eggs. Due to their cryptic nature but dependence upon these fixed mounds for nesting, Malleefowl populations are most efficiently monitored by regular assessment of the activity of mounds. Disused mounds can persist in the environment for many decades, with historic mounds distinguished from more recently used mounds by increasing crusting of lichen or moss with age of the mounds. Inspection of mounds in a specified area over time can therefore facilitate appraisals of whether nesting densities have increased (low percentage of historic mounds) or decreased (high percentage of historic mounds) in recent decades.

Strategic and representative monitoring of mound activity is dependent upon comprehensive understanding of the distribution of mounds. Malleefowl mounds are commonly surveyed using ground-based foot searches over grids, often two to four square km in area (ref National Malleefowl Monitoring guidelines). Lines of walkers, spaced sufficiently to sight mounds between adjacent observers, are used to traverse the grids. In recent times alternative methods of searching for mounds have developed, including tracking Malleefowl tracks to their mounds, aerial surveys via helicopter, and remote sensing tools using infrared, high definition photography and Light Detection and Ranging (LiDAR).

Over 150 Malleefowl mounds had been located through opportunistic foot-based surveys from 2008-2013 within a 50,000 hectare area of the Middleback Alliance region of north-eastern Eyre Peninsula, South Australia. However, this count is likely to represent only a fraction of the mounds in the study area, as less than 20% of the region has been traversed. Determining the most accurate and cost effective technique for locating Malleefowl mounds in dense mallee vegetation will enhance the ability to monitor, and perhaps manage, populations of this nationally threatened species.

This study compared the relative efficacy of walking grids, helicopter based visual surveys and LiDAR transects at detecting Malleefowl mounds in the mallee of the Middleback Alliance region.

***Methods***

*Study Site*

Middleback Alliance region encompasses three conservation parks (Lake Gilles, Sheoak Hill and Ironstone Hill), one private nature reserve (Secret Rocks) and numerous Heritage Agreements and pastoral leases. The habitats vary from open mallee woodland to chenopod shrubland with granite rock outcrops and *Triodia* sand dunes. The majority of the Malleefowl mounds are found within sandy mallee sections of the region covering approximately 100,000 hectares  Five grids, each measuring approximately 1km x 1km were selected in areas considered to be favourable for Malleefowl for detailed survey.

<u>Helicopter surveys</u>

Helicopter-based aerial surveys were conducted from a helicopter flying at approximately 150 metres above ground level over five x 1 $km^2$ search grids in April 2013. Three grids were established on Secret Rocks Nature Reserve and two on Ironstone Hill Conservation Park.  Each grid was surveyed by six to eight passes, approximately 100 metres apart. When a suspected mound was spotted, the helicopter would circle or hover above the mound to confirm the observation and record an accurate location on a handheld GPS. The helicopter travelled at a speed that the spotter was comfortable with and would enable a thorough survey, with the pilot asked to slow down if necessary. Surveys were conducted in the Shirrocoe east, Shirrocoe west and Sandy grids between 14:30 and 15:15 on April 30, 2013 and on the Powerline and Bluey grids 11:00-11:40 on May 2, 2013.

<u>Ground surveys</u>

Strategic ground-based walking surveys were conducted in November 2013 throughout the same five x 1 $km^2$ grids that had been surveyed by the helicopter. Four to five walkers traversed the grid at a spacing of approximately 20m where they were comfortable they could sight their neighbouring walkers' feet. The outside walkers on each transect marked their trail on a handheld GPS to set the course for subsequent transects and ensure adequate coverage. When any walker observed a mound the line stopped whilst the mound location was recorded before the line resumed the search. This method closely followed that outlined in the National Malleefowl Monitoring guidelines.

<u>LiDAR surveys</u>

LiDAR technology was utilised during a survey of Malleefowl mounds within two 500m wide transects through the Middleback Alliance area as part of an environmental assessment for a proposed high voltage powerline. One of these LiDAR transects traversed two of the Malleefowl mound grids surveyed by helicopter and ground searches.

A Bell 206B-3 JetRanger (C20J Turbine) aircraft flown at 325m above ground level and 60 knots, equipped with an Optech Orion LiDAR Sensor, using nominal point density of 20+ points / $m^2$,  was flown over the transects between 30 November and 2 December 2013. A relative system accuracy of 2 cm on both horizontal and vertical scales was achieved. A DiMAC 51 mm image sensor captured imagery at a resolution of 4 cm. Orthophotography was provided at a resolution of 10cm pixel size with a horizontal accuracy of 10cm. Data analysis and modelling was conducted from 16 December 2013 to 26 February 2014.

By exaggerating the vertical scale of the surface created by the LiDAR ground points most mounds were clearly visible (Figure 1) and a 3D point was manually placed by operators in the centre of objects of similar size and shape to Malleefowl mounds. A total of 253 objects were identified but cross-checking with orthorectified photos suggested that a percentage of these objects were not Malleefowl mounds. To eliminate most of these false positives an algorithm was created to eliminate all objects with an arbitrary height lower than 25cm above the surrounding plain, which eliminated 80 of the identified objects. The remaining 173 objects (from both transects) were reviewed using the LiDAR ground points and the orthorectified imagery to differentiate between objects with a concave apex and those with a domed apex. This process differentiated 81 'confirmed' mounds (Figure 1) with a concave shape and 92 'possible' mounds which were flat or domed.

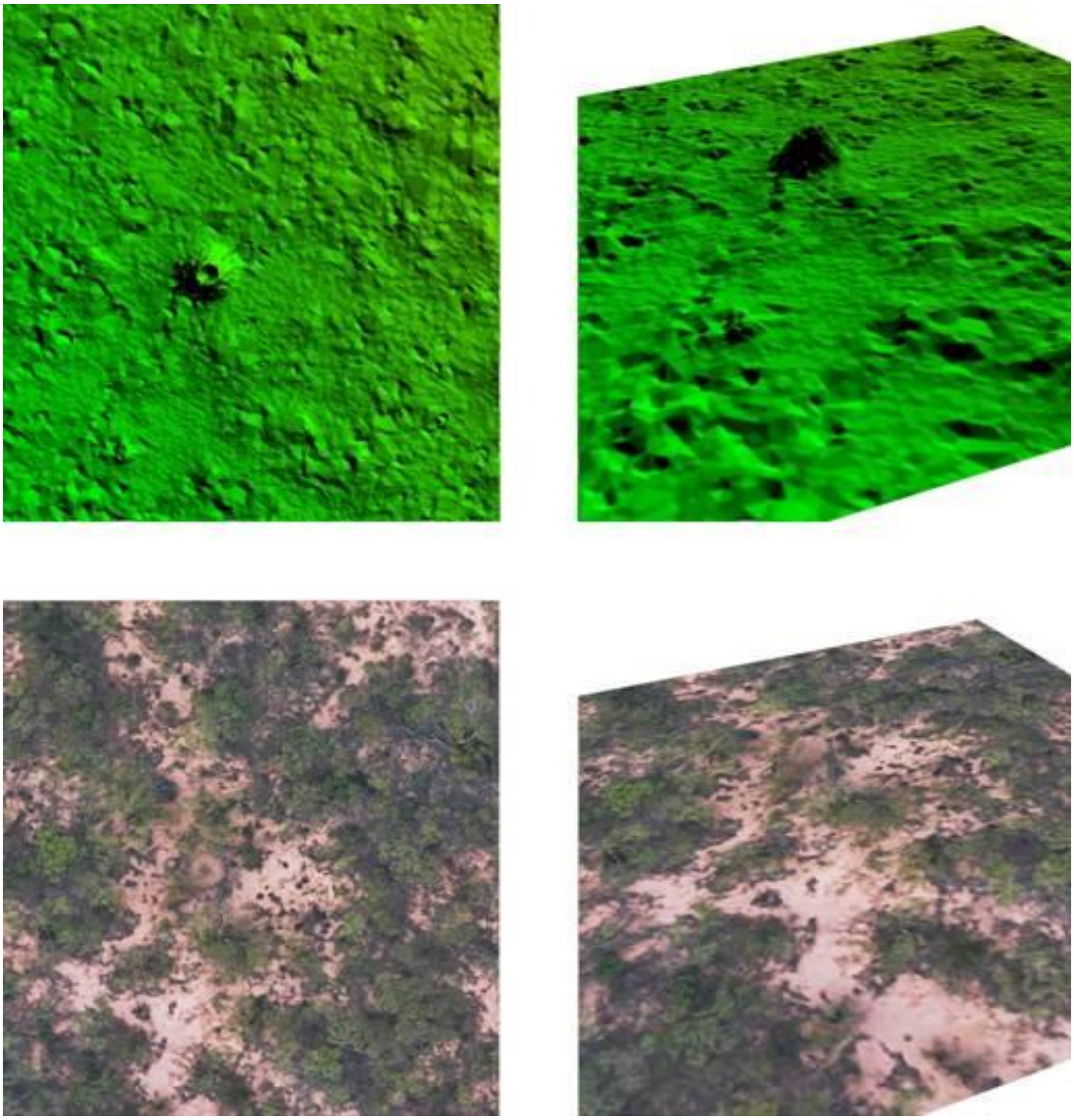

**Figure 1.** Examples of LiDAR (top row) and aerial photography (bottom row) (used to 'confirm' mounds) for Malleefowl mound MA78.

Validation and comparison of techniques

The accuracy of the LiDAR detections was assessed by ground truthing 137 of the 173 identified mounds, comprising 67 (83%) of the 81 'confirmed' and 70 (76%) of the 92 'possible' mounds. Ground truthing was conducted by John Read of Ecological Horizons in March and April 2014. The dimensions and characteristics of all visited mounds were scored using standard National Malleefowl Mound Monitoring guidelines. 'Historic' mounds were distinguished from more recently active mounds by moss or lichen (Figure 2). Incidentally, several earthen mounds, presumably created during the powerline construction, exhibited similar degrees of crusting as these historic mounds. Additionally, by overlapping the flight path of the helicopter, the walking path of the ground surveys and the LiDAR corridor for two of the five survey grids, the location of mounds recorded by each technique could be compared to assess each technique's relative efficacy.

**Figure 2.** Old Malleefowl eggshell, moss and lichen on a historic Malleefowl mound (C056).

Costings

For the purposes of comparing the costs of the different techniques the following rates were used to determine costs per square kilometre:

| | | |
|---|---|---|
| • Field work time for ground surveys | 20hr @ \$50/hr | = \$1,000 per km$^2$ |
| • Helicopter time | 10 mins @ \$950/hr | = \$158 per km$^2$ |
| • LiDAR costs | (see table 2) | = \$ 311 km$^2$ |

No mobilisation costs were incorporated into any of the estimates and these will obviously vary considerably depending on access to aircraft and field personnel. The LiDAR estimate is only for 'confirmed' mounds and does not include ground truthing. Likewise the helicopter survey did not include ground truthing, as all mounds identified by helicopter were also independently located by the ground-based survey.

***Results***

Grid searches

A total of 35 mounds were detected from the five grids surveyed by helicopter, LiDAR and ground-based searches. Plotting of the exact routes of the helicopter and walkers revealed slight disparities in the area of each grid covered, which explains the different total mound counts on two of the five grids (Table 1). The LiDAR transect only intersected part of the Shirrocoe E and Bluey grids. The total mounds detected on grids using all three techniques were assumed to represent the total mounds present on each grid. Ground-based searches detected all but two (94%) of the total mounds known to be present. The two mounds not located by the ground searches were in the very densely vegetated Bluey grid (Table 1). These additional mounds were detected (and subsequently confirmed on the ground) by LiDAR on one of the two grids traversed by LiDAR and hence it is possible that other mounds were also missed by the ground-based surveys. Eleven mounds were detected by the helicopter survey, with nine of the 14 mounds present detected from the three grids surveyed in the afternoon and two of the 15 mounds detected from the grids surveyed in the late morning, with a mean detection frequency of 37% of the mounds located by this technique (Table 1). The LiDAR survey located six of the ten mounds on grids that it traversed but two of the 'missed' mounds were calculated to be within ten metres of the far edge of the LiDAR transect and may have been inadvertently not included in the transect (Table 1).

Because the helicopter hovered low over any mounds before they were recorded, all mounds recorded from this technique were subsequently confirmed to be mounds.

**Table 1.** Ratio of mounds recorded by the three techniques and relative cost per mound recorded of helicopter and foot based surveys.

| Grid ID | Helicopter | | Foot | | LiDAR |
|---|---|---|---|---|---|
| | **Ratio found** | **$ per mound** | **Ratio found** | **$ per mound** | **Ratio found** |
| Shirrocoe W | 3/5 | $53 | 5/5 | $200 | na |
| Shirrocoe E | 4/4 | $40 | 7/7 | $142 | 3/5 * |
| Sandy | 2/6 | $79 | 6/6 | $167 | na |
| Bluey | 1/9 | $158 | 9/11 | $111 | 3/5 |
| Powerline | 1/6 | $158 | 6/6 | $167 | na |
| **Total** | **11/30** | **$72** | **33/35** | **$151** | **6/10** |

* Two undetected mounds were within 10m of edge of LiDAR strip

**Table 2.** Cost breakdown for this LiDAR survey and cost savings with potential modifications.

| | Unit cost | Total cost | Cost km$^2$ | Cost per mound |
|---|---|---|---|---|
| Helicopter | 2h @ $2400 | $4800 | | |
| LiDAR equip & operation | 2h @ $850 | $1700 | | |
| Processing & quality check | 50h @ $150 | $7500 | | |
| **Total this survey** | | **$14000** | **$311** | **$181 ( 'confirmed')** |
| Fixed wing | 1h @ $1200 | $1200 | | |
| LiDAR equip & operation | 1h @ $850 | $850 | | |
| Processing | 22.5hr @ $150 | $3375 | | |
| **Total simplified survey** | | **$5425** | **$120** | **$70 ('unconfirmed)** |

**NOTE:** These estimates do not include mobilization and standby fees and should be seen as ballpark figures. There are economies of scale that will have an influence on cost; usually the bigger the area the lower the per sq. km rate.

LiDAR transects

Seventy confirmed mounds were detected by the LiDAR survey, bringing the known count of Malleefowl mounds in the Middleback Alliance area to 245.

In total, 95% (64 of 67) of the 'confirmed' objects identified by LiDAR were found to be Malleefowl mounds by ground truthing. The other three false positive objects were circular earthen mounds created by earthmoving equipment. By contrast, only 8.5% (six of 70) of the 'possible' objects were confirmed to be Malleefowl mounds. Several of these false positives were the elevated lignotubers of mallee trees (Figure 3) although most were piles of soil left by the creation of firebreaks or the construction of a powerline and access track. Of the 66 mounds identified by the LiDAR search and confirmed by ground truthing, the average depth of the central cone was 34.8cm (range 5 - 90cm), the average height of the mound rim above the ground surface was 24.4cm (range 2 - 47mm) and the average differential height between the rim and the bottom of the cone was 59.2cm (range 10 - 125cm) (Figure 4).

Sections of the LiDAR transects included areas of cleared land or unsuitable chenopod shrubland habitat, leaving 65.8km considered to traverse potentially suitable Malleefowl habitat. Together these data suggest a density of 2.6 mounds per square kilometre throughout the region, which is considerably less than the average of seven mounds per square kilometre detected from the five grids selected in prime Malleefowl habitat (Table 1).

The only two mounds identified by LiDAR that were likely to have been active in the previous summer were considered to be 'possible' rather than 'confirmed' mounds. Active mounds may alter from having a concave shape to a domed shape over the course of a day (Fig. 3), and it is likely that these mounds were indeed mounded and active when the LiDAR was flown. Improvements in the algorithm used to distinguish mounds from LiDAR data to include these convex mounds, would likely improve the percentage of active mounds correctly assigned as 'confirmed' and possibly decrease the number of mounds not detected (false negatives) by the LiDAR. Furthermore, incorporation of the differential height (from rim crest to the central low point of the mound) into the LiDAR algorithm may further increase detectability and also allow mounds of different profile to be distinguished.

**Figure 3.** P89 is an example of a potential mound that was in fact the elevated lignotubers around a mallee stump.

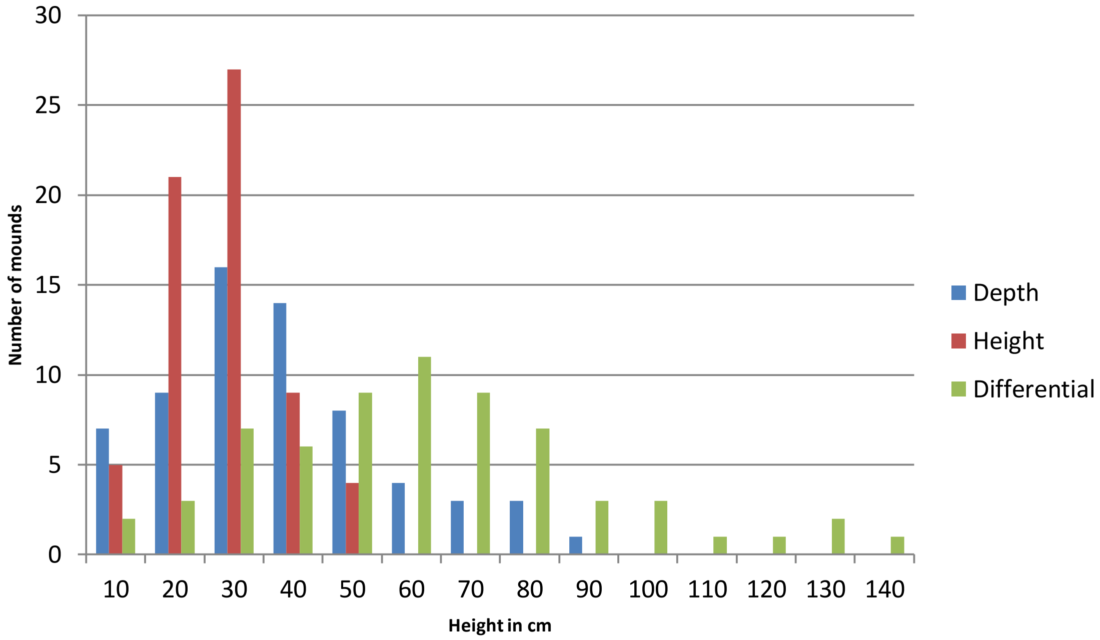


**Figure 4.** Depth and height dimensions of the 65 mounds detected by LiDAR in the Middleback region and the differential height between the rim of the mound and the bottom of the central cone.

<u>LiDAR false negatives</u>

Four mounds confirmed by ground searches along the LiDAR transects were not identified by the LiDAR survey. One of these, MA108, was identified by the LiDAR operators but discarded because, like the other three false negatives, its height above ground level was lower than the arbitrary 25cm cut-off. Two of these undetected mounds had previously been located in the 1 $km^2$ grids methodically surveyed by helicopter and on the ground.

Low percentages of active nests (two from 70, 2.9%) along LiDAR transects and the surveyed grids recorded in this survey was consistent with low nesting success recorded by the Middleback Alliance monitoring program in 2013, when only 2 of 127 monitored mounds (1.6%) were recorded as active in the same region. This low nesting effort is believed to be related to environmental conditions and contrasts markedly with activity levels of 12.9%, 22.3% and 24.7% in the years 2011, 2012 and 2013 respectively.

<u>Costs</u>

The helicopter costs of $900 per hour did not include mobilisation costs of $6,300 because the Malleefowl search was conducted whilst the helicopter was based locally for feral goat control operations. Mobilisations costs would need to be factored into the costings if the Malleefowl mound surveys required separate mobilisation.

Each of the walking grids took an average of five people a full day to conduct by the time they were briefed and transported to and from their sites from the base camp. Fuel and food reimbursement for this weekend campout amounted to $2,400, or $480 per 1$km^2$ grid.

The LiDAR transect was flown as part of a broader contract including other deliverables for an electricity supply company, which meant that mobilization costs and the greater expense incurred by high density LiDAR were covered independently from the Malleefowl mound survey.

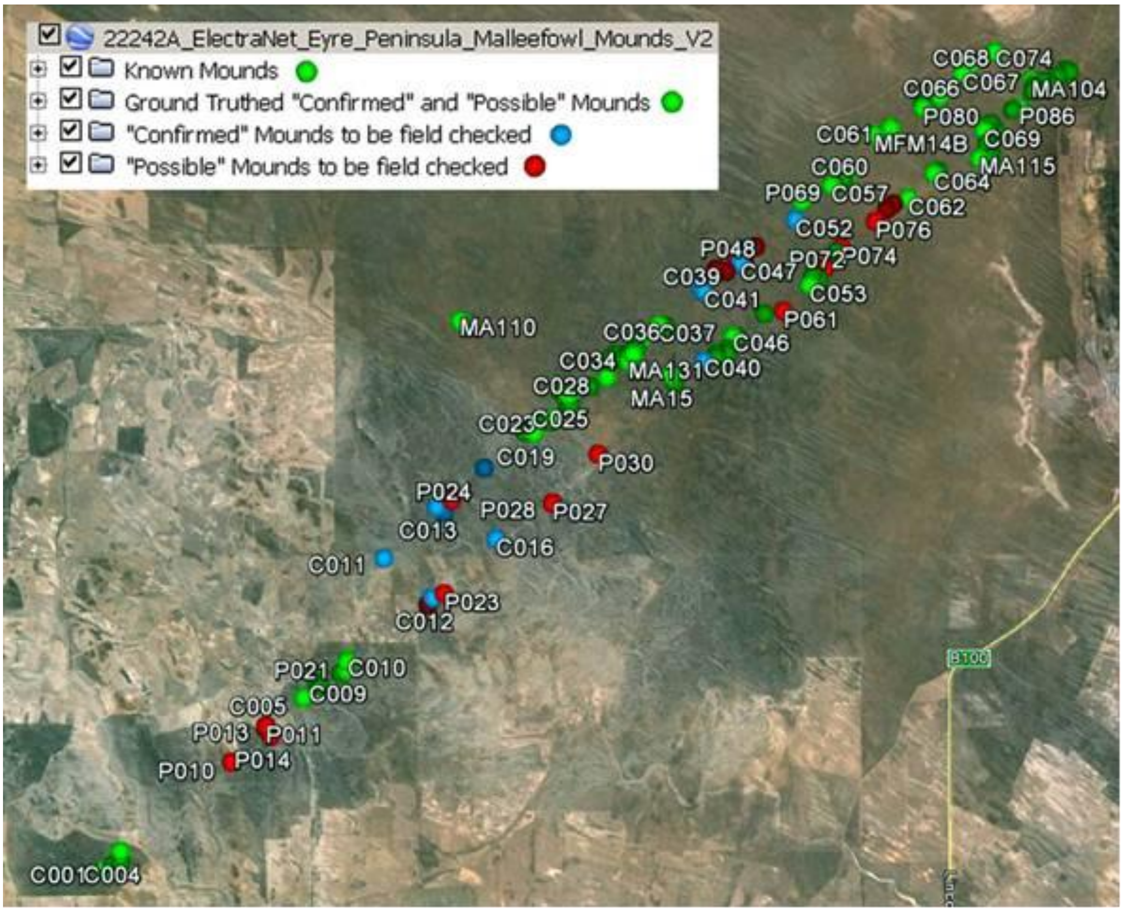


**Figure 5.** Green dots: confirmed (ground-truthed) Malleefowl mounds; blue dots: not ground-truthed but 95% likely based on confirmed percentage of 'confirmed' objects; red dots: not ground-truthed but 8.5% likely (based on confirmed percentage of 'possible' objects).

### *Discussion*

This survey revealed average Malleefowl mound density of 2.6 mounds per km$^2$ throughout the intact mallee vegetation in the Middleback Alliance region of NE Eyre Peninsula. This density is approximately one third of the median mound density for Malleefowl sites in South Australia but relatively high for an arid region (J. Benshemesh pers. comm.). Less arid areas with high density mounds are typically restricted to smaller isolated remnants suggesting that the Middleback Alliance region, whilst supporting lower mound density, is supporting a significant Malleefowl population due to the large area of intact habitat.

The LiDAR survey was the most widespread and accurate Malleefowl mound survey technique used in this survey. On the basis of the false negative records verified by ground searches, those mounds identified by LiDAR are assumed to constitute 69-72% of the mounds within the transect. A high percentage of the mounds not identified by LiDAR were historic low mounds that did not protrude more than 25cm above the surrounding ground surface. These mounds are of relatively low importance to the management and monitoring of Malleefowl populations compared with the active or recently active mounds.

Confirmation of false positives identified by LiDAR was straightforward because identified objects could be ground-truthed. However determining the percentage of false negatives, or mounds that were not detected by LiDAR, was compromised by difficulty in determining the exact boundaries of the LiDAR transect. Uncertainty about the precise extent of the LiDAR survey area is best managed by including a slightly wider strip, or overlapping strips over the area of interest.

The Middleback Alliance study suggests that although conventional ground based surveys are the most accurate and informative technique for surveying Malleefowl mounds, LiDAR offers a valuable tool to search for Malleefowl mounds, particularly in dense scrub that is difficult to walk through. Given that the quality assurance provided by cross checking LiDAR identified objects with photographs cost in excess of $3,000 but was not able to reliably identify active mounds, savings could be generated by providing the unverified positions of objects identified by the LiDAR algorithm without this office-based quality assurance.

Helicopter-based surveys may be beneficial in rapid detection of Malleefowl mounds, especially where ground access is difficult. However our experience is that these aerial surveys located only about a third of the mounds, with many concealed by shadows or shielding vegetation. Therefore, whilst allowing rapid location of mounds for monitoring purposes, we would not advocate helicopter based surveys when the location of most mounds in an area is required.

Optimal Malleefowl mound survey techniques depend upon the required precision and relative costs of ground based surveys or ground truthing in the search area. LiDAR costs would be reduced by approximately 200% through use of a fixed wing aircraft, especially if mobilisation costs can be minimised, together with reduced precision (from 20 to 4 points per $m^2$) and reducing the quality assurance process through comparisons with aerial photographs rather than ground truthing all mounds.

Aerial techniques such as LiDAR and helicopter surveys obviously benefit from economies of scale whereby the per-hectare or per-mound costs reduce with increasing size of the search area.

In extensive areas that are difficult to access on the ground or if accurate locations of mounds are required urgently, we recommend use of detailed LiDAR assessment combined with office-based quality assurance using orthorectified aerial photography, that was used in this trial.

Where ground-based verification or detailed measurements are necessary we suggest that less precise LiDAR (e.g. 4 points per $m^2$) combined with automated ID and removal of objects less than 25cm high would be more economical. This less precise technique will generate more false positives and hence require greater field verification.