A SPATIAL ANALYSIS OF GREATER BILBY (*MACROTIS LAGOTIS*) HABITAT IN SOUTH-WEST QUEENSLAND

Ernest. Dunwoody[1], Xiaoye. Liu[1], and Kevin. McDougall[1]
[1]Faculty of Engineering and Surveying, University of Southern Queensland
Toowoomba, QLD, 4350, Australia
Email: edunwoody1@bigpond.com

ABSTRACT

Greater Bilbies (*Macrotis lagotis*) once occupied 70% of Australia but are now an endangered species under the Environment Protection and Biodiversity Conservation Act (C'wlth) 1999. A dedicated 29 km^2 enclosure to protect reintroduced bilbies from predators was built in Currawinya National Park in south-west Queensland in 2003. Ten bilbies (three male and seven female) were released in the enclosure during the period of December 2005 to September 2006.

The objective of this research was to develop a method to identify suitable Greater Bilby habitat from remote sensing imagery. A related objective was to spatially characterize how bilbies used their environment for feeding and resting. Aerial photographs (1:40,000) were used to classify the vegetation and land cover. Soil samples were used to construct a detailed soils map. Radio tracking (2005-06) and field tracking data (2008) were used to identify spatial associations between bilby activities and land cover and soil features in order to spatially characterize bilby micro-habitats. These results formed the basis of a Weighted Sum model that accurately identified potential bilby micro-habitats within the enclosure.

The analysis showed that bilbies prefer to dig burrows in Acidic Rudosol soils with Shrubland with Dead Wood landcover. Their feed sites occur fairly evenly on Acidic, Basic and Salic Rudosol soils but they preferred Shrubland landcover in which to feed.

The modelling results showed that, (i) bilby feeding and resting micro-habitat could be accurately predicted within the confines of the enclosure, (ii) bilbies depended on only a small part of the larger area available to them, (iii) bilbies exhibited distinct preferences for specific soil and landcover types for constructing burrows and feeding and (iv) micro-habitats suitable for bilbies represent only a small percentage of the enclosure.

KEYWORDS: Greater Bilby, marsupial habitat, spatial analysis, remote sensing, GIS, habitat modelling, Weighted Sum, soil mapping, landcover classification

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INTRODUCTION

The Greater Bilby (*Macrotis lagotis*) is a small, cryptic, nocturnal, fossorial marsupial in the Peramelidae Family (Figure 1). It is one of Australia's most endangered marsupials[10], its range having declined 99.7 % since 1836 (McRae 2004, p. 111). It remains in the wild in only small areas of arid inland Australia (McRae 2004, p. 106; Southgate 1990a, pp. 295-298). Populations are maintained in protected areas in South Australia (Moseby & Donnell 2003), New South Wales (Finlayson, Vieira, Priddel et al. 2008, p. 320) and Queensland (Mayhew 2006, p. 5).

Figure 1. Greater Bilby *(Macrotis lagotis)* (© QEPA)

The Greater Bilby is a generalist omnivore that can live in a wide range of habitats as evidenced by its historically broad distribution. Vegetation types range from *Acacia* rich woodlands through shrub steppe communities to tussock and forbs grasslands (Southgate 1990b, p. 111). Lavery and Kirkpatrick (1997, p. 274) reported bilbys burrowing in "stone free Cretaceous sediments of cracking clays" that occur in grassland downs adjacent to the watercourses in Davenport Downs (SW QLD). McRae (2004, pp. 10, 71-72) reported that the bilbies in Astrebla Downs National Park built burrows in areas of suitable soil structure and stability that included "Compacted sandstone outcrops in deep cracking clay soils of the ashy plains --- along drainage depressions". Bilbies in the Tanami Desert (NW of Alice Springs) were reported to preferentially occupy palaeodrainage habitats (Paltridge & Southgate 2001, p. 255). Bilbys released at the Arid Recovery Reserve north of Roxby Downs (SA) were found to prefer clay swale habitat, dunes and sand plains (Moseby & Donnell 2003, p. 19).

The reduction in their population and range has been caused primarily by predation from red foxes (*Vulpes vulpes*) and cats (*Felis catus*), habitat destruction by domestic and feral herbivores, increased provision of watering points and by past government bounty policies (Hrdina 1997). Recolonisation of bilbies into "wild like" protected areas from which predators have been excluded has been successful at Thistle Island and Yookamurra Sanctuary in South Australia (Moseby & Donnell 2003), Scotia Sanctuary in New South Wales (Finlayson et al. 2008, p. 320) and in the Bilby Enclosure (BE) in Currawinya National Park (CNP) in Queensland (Mayhew 2006, p. 5).

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[10] Vulnerable under Schedule 1 of the Environment Protection and Biodiversity Conservation Act (Cwlth) of 1999 (Pavey, C. 2006, *National recovery plan for the Greater Bilby Macrotis lagotis.*, Darwin)

Small animals cannot be detected directly by aerial or satellite photography. Their habitats can only be determined indirectly by detecting and mapping combinations of vegetation, soil and landscape elements and developing associations between these features and the target animal. Southgate et al (2005) assessed bilby abundance in the Tanami Desert by looking for their footprints, scats and diggings. Their ability to identify bilby tracks was not obscured by vegetation or rabbits. McRae (2004, p. 77) reported that "bilby burrows were readily visible from the air" due to their excavation of different coloured subsoil in the open treeless area between the Diamantina River and the Simpson Desert. Such knowledge must be able to be summarised and represented spatially before it can be used in habitat mapping.

GIS systems allow interaction between data at different spatial and temporal scales (Store & Jokimäki 2003). Multi-Criteria Evaluation (MCE) in a GIS environment allows cartographic combination of multiple habitat factors so as to detect their influence on the suitability of the habitat for a species. Store and Kangas (2001, p. 79) demonstrated this approach to predicting habitat suitability for the polypore fungal species *Skeletocutis odora* and subsequently with three species simultaneously, the Redstart (*Phoenicurus phoenicurus*), Pied Flycatcher (*Ficedula hypoleuca*) and *S. odora* (Store & Jokimäki 2003). Apan et al (2004, p. 812) used a knowledge based MCE GIS method to identify areas of high priority for revegetation to ameliorate dryland salinity in the Hodgson Creek watershed (Darling Downs, Qld).

The absence of a geographical knowledge base about bilby activity at CNP necessitated the development of an empirical data set. This required obtaining detailed evidence of bilby activity in a wooded environment containing a significant rabbit population and the extraction of indicator relationships for bilby activity.

The objective of this research was to test the use of aerial photography for detecting suitable landscape elements with which to predict the suitability of habitat for Greater Bilbys in the BE at CNP. Imagery captured prior to release of bilbys was used to develop a model of suitable burrowing and feeding sites based on activity records of the bilbies that were subsequently released. The accuracy of the model for detecting bilby activity elsewhere in the enclosure was tested on separate validation areas.

METHODS

Study Areas

The study area was the 29 km^2 BE in CNP built in 2003-2004 (Figure 2). It was designed to exclude all ground based predators of bilbys while retaining the released bilbys and their offspring.

Field Data Collection

Detailed data about soil characteristics and bilby activity were collected at eight investigation areas selected at random within the BE (Figure 2). Trimble GeoXT hand held GPS units loaded with TerraSynch software were used to collect both base station and field observations. All GPS data were differentially corrected.

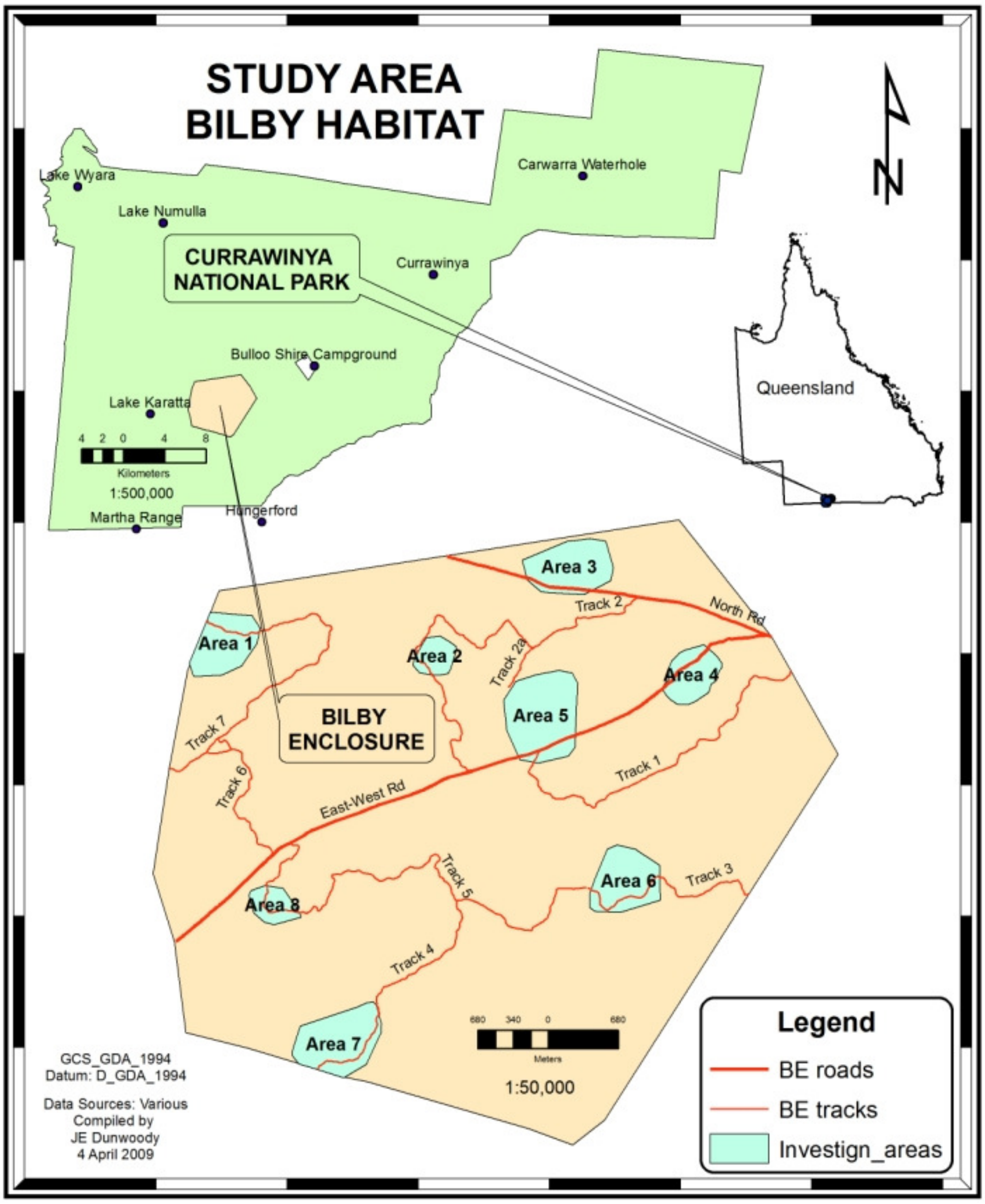

Figure 2. Study Area

The key GPS settings were: observation interval, 5 sec.; observations per feature, 20 (min); and HDOP, 6 (max). These values resulted in data with the following precision.

Differentially corrected feature		Non-differentially corrected feature	
Mean	= 2.18 m	Mean	= 10.32 m
SD (95%)	= 0.12 m	SD (95%)	= 0.11 m

Signs of bilbies were recorded in a GPS data dictionary by a trained observer walking in a series of roughly concentric circles through each vegetation zone in each of the eight investigation areas.

Data Pre-processing

Six aerial photographs acquired in June 2003 by a private contractor (Jacobs 2003) were used based on their availability, clarity and resolution. The images were captured during the period 18-23 May 2003 at a flying height of 3,229 m with a calibrated 80 mm focal length Hasselblad lens resulting in imagery with a scale of 1:38,800. The pixel size was 0.6682 m. Each image was georeferenced and the images were mosaiced with ERDAS Imagine software (Ver.9.3). The mosaiced image was linearly stretched and dehazed prior to Supervised Classification using the maximum likelihood classifier. The resulting raster was reclassified into 5 Landcover Classes and a final Accuracy Assessment performed using 50 randomly stratified sites. A soils map was created by heads-up digitising based on an observed association between the soil types and broad vegetation zones.

DATA ANALYSIS

The spatial association of burrows and feed sites with soil and landcover types was determined by spatially joining the data sets and extracting the positive joins. The area of soil types and landcover classes that were inspected was obtained by buffering each track path (5m either side) and extracting the area of each soil and landcover type.

The frequencies of burrows and feed sites were used as class weights in multiple Weighted Sum Overlay (WSO) calculations to determine the combination of layer weights and classification break points that maximised the number of bilby signs in high priority areas. The predictive accuracy of these values was determined by vectorising the WSO rasters, spatially joining them with field records and analysing the distribution of the joins between priority areas.

RESULTS

When averaged, normalised, and expressed on a common basis (0-10) the burrow and feed site weights had the following values (Tables 1 and 2).

Table 1. Burrow Site Weights

Soil Class	Weight	L'cover Class	Weight
Hydrosol	0	Claypan	0
Salic Rudosol	3.58	Red Soil	1.54
Basic Rudosol	0	Shrubland	0
Acidic Rudosol	6.42	S'land with dead wood	6.83
		Thick Vegetation	1.63
Total	10.00	Total	10.00

Table 2. Feed Site Weights

Soil Class	Weight	L'cover Class	Weight
Hydrosol	0	Claypan	0
Salic Rudosol	3.24	Red Soil	1.65
Basic Rudosol	3.09	Shrubland	3.73
Acidic Rudosol	3.66	S'land with dead wood	2.22
		Thick Vegetation	2.39
Total	10.00	Total	10.00

The most accurate prediction of burrow sites and feed sites was obtained by weighting the landcover layer as twice as important as the soil layer. Manual classification break values that yielded the highest accuracy are shown in Table 3.

Table 3. Classification Break Values

Priority	Burrow Site Break Value	Feed Site Break Value
Low	0 – 4	0 – 6
Medium	4 – 14	6 – 7
High	14 – 21	7 - 10

These values were used to produce maps of Burrow and Feed Site Priority areas for the whole of the BE. Figure 3 shows an illustration of such mapping for Study Area 4.

The model predicted high priority locations for burrow sites and feed sites with a 67% and 84% accuracy respectively in the areas in which it was developed (Areas 2, 4 and 7) (Table 4).

Table 4. Study Area Accuracy

Parameter	Feature	Predicted priority of sites						
		High	SD	Medium	SD	Low	SD	Total
Totals	Burrows	4	1.53	2	0.58	0	0	6
	Scrapes	64	5.77	7	2.31	5	1.53	76
Percent	Burrows	67%		33%		0%		100%
	Scrapes	84%		9%		7%		100%

When validated in independent areas (Areas 1, 3, 5, 6, and 8) the model predicted high priority locations for burrow sites and feed sites with 84% and 80.5% accuracy respectively (Table 5).

Table 5. Validation Area Accuracy

Parameter	Feature	Predicted priority of sites						
		High	SD	Medium	SD	Low	SD	Total
Totals	Burrows	16	4.60	1	0.45	2	0.65	19
	Scrapes	70	9.08	10	2.35	7	1.52	87
Percent	Burrows	84%		5%		11%		100%
	Scrapes	80.5%		11.5%		8	5	100%

Combining the burrow and feed site priorities into an overall Habitat Suitability Map identified areas in which both or either criteria was a high priority. This is illustrated in Figure 4.

DISCUSSION

The model is based on a Weighted Sum Overlay approach to predicting suitable burrow and feeding locations for bilbys in the BE at CNP. It uses data derived from aerial photography, soil sampling and ground presence tracking. The model was validated by using an independent subset of the ground truth records. It predicted high priority burrow and feed sites with 84% and 80.5% accuracy respectively. No reports of other studies on predicting specific habitats for small marsupials were found. These results need to be considered in the light of the limitations inherent in the procedures.

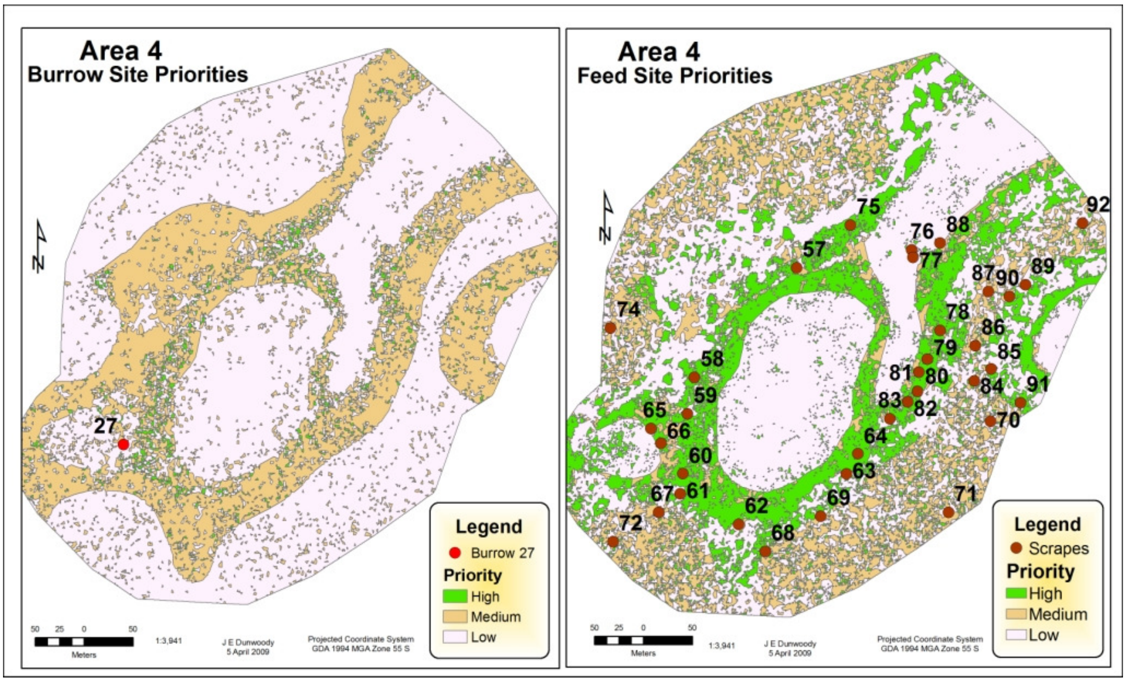

Figure 3. Burrow and Feed Site Priority Locations for Area 4

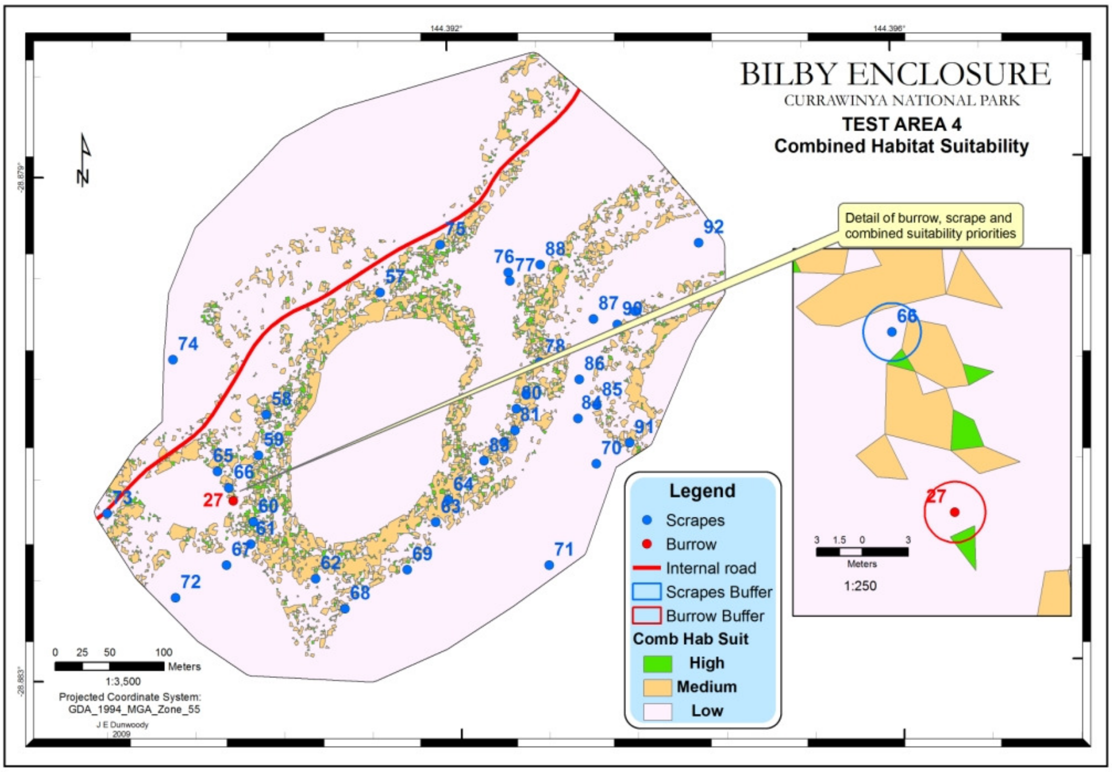

Figure 4. Combined Habitat Suitability detail for Test Area 4

Burrow and Feed Sites

Previous studies have established the importance of soil type in habitat selection by bilbies. This study found that bilbies dug burrows in Acidic Rudosol soils twice as frequently (6.42) as in Salic Rudosol soils (3.58). There was no evidence of bilby burrows in Basic Rudosol soils or in Hydrosols. They chose Shrubland with Dead Wood landcover twice as frequently (6.83) in which to burrow compared to exposed Red Soil (1.54) and Thick Vegetation landcover (1.63). These findings are consistent with Mayhew's (2006, p. 79) more generalised findings for the BE.

The bilby burrow data used in this study were an amalgamation of burrow location data collected by previous investigators by radio-tracking in 2005-2006 (McRae 2008 pers. comms.) and visual tracking data collected for this study. Prediction of burrow habitats was based on 6 burrows in the three study areas and the results were validated using a further 19 independent burrow locations. The small sample size of the predictor burrow habitat is recognised as being less than optimal, however the validation on a further 19 burrow locations supports the model outcomes.

Feed sites selected by bilbies were relatively evenly distributed between all three Rudosol soil types but there were none in Hydrosols. Shrubland landcover was preferred for feed sites (3.73) over Shrubland with Dead Wood (2.22) and Thick Vegetation landcover (2.39). These findings were based on 76 clusters of scrapes in the study areas and a further 87 clusters in the areas used for validation.

Analysis of the whole enclosure found that there were more areas of high priority for feeding than for burrowing (Figure 3). This finding was anticipated. Combining the burrow and feed site priority areas defines the areas suitable for both resting and feeding. The combined map of burrow and feed sites (Figure 4) shows the areas in which both are a high priority, or either one of the two is a high priority. McRae (2004, p. sec. 2.3.2) documented the capacity of bilbies to forage at distances of hundreds of meters from their refugia. It is therefore not surprising to find some record of feed sites outside the high and medium priority habitat areas.

Precision and Accuracy

The Overall Classification Accuracy of 80% and Kappa Index of Agreement of 0.76 were considered satisfactory for classification of aerial imagery without an NIR band into 5 landcover classes. The model accuracy results (Tables 4 and 5) are comparable to or better than accuracies obtained by other models. Pasher, King and Lindsay (2007), using Landsat 5 and Ikonos imagery, reported model accuracy of 70% for nest sites for the Hooded Warbler (*Wilsonia citrinia)* in the validation area. Allowing for a 10 m error zone increased their accuracy to 87%. The bilby model's use of a 95% probability level resulted in a more stringent accuracy test than if a 99% probability level had been used. The accuracy was scored according to the highest priority polygon that lay partially or wholly within the 95% horizontal precision zone (Figure 4, subset).

CONCLUSION

This study demonstrated a procedure by which aerial photography can be used to identify areas suitable for Greater Bilby burrow and feed sites with a high level of accuracy. Physical tracking and GPS recording of bilby signs was shown to be a practical and effective method of collecting geographically referenced information about bilby habitat. Bilbys exhibited strong preference for specific types of soil and landcover in which to burrow. Application of the model to the 29 km^2 enclosure established that there are extensive feeding sites within foraging range of all potential burrow sites in the Enclosure. The applicability of these results is limited by their dependence on aerial photography. Use of more widely available imagery with greater spectral and less spatial resolution would allow (i) application to a wider area, (ii) more accurate soil type classification, and (iii) integration with other land management issues.

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BIOGRAPHY OF PRESENTER

Ernest Dunwoody is a post-graduate student at the University of Southern Queensland studying for a Masters Degree in Spatial Science Technology. He holds a Bachelor’s Degree in Agricultural Science (Entomology) from the University of Queensland, and a Graduate Diploma in Geomatic Studies from the University of Southern Queensland.