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The Role of Trees in Facilitating Landscape Connectivity

A Spatial Analysis Approach for Solar Farm Design

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1.0 Introduction

Habitat fragmentation is a key threatening process to biodiversity in south eastern Australia. Habitat fragmentation comprises four impact pathways - a reduction in habitat amount, an increase in the number of habitat patches, a decrease in the size of habitat patches, and an increase in the isolation of patches (Fahrig 2003).

Scattered trees play an important role in fragmented landscapes. They reduce the habitat patch isolation effect by acting as ‘stepping-stones’, particularly for bird, bat and arboreal mammal species. The avoidance of clearing habitat patches or scattered trees is crucial for the maintenance of habitat connectivity in a region. However, it is recognised that land development may require clearing of some patches in a landscape. Methods to describe habitat connectivity and the value of these patches are complex and vary depending on different species.

A review of Australian policies and legislation demonstrated significant inconsistencies between States regarding the recognised value of paddock trees, methods to measure this value, and levels of protection afforded to paddock trees.

This document synthesises information on the role that Large Trees in Patches (a surrogate for remnant vegetation patches) and scattered paddock trees play in providing habitat connectivity in a fragmented landscape. It also discusses ways of measuring habitat connectivity and critical distance thresholds between habitat features such as remnant patches, scattered paddock trees, dams and waterways for different fauna species. This information has been utilised to develop a set of spatial parameters to categorise Large Scattered Trees (LSTs) and Large Trees in Patches (LTPs) in relation to their perceived value as stepping-stones within the landscape.

The spatial parameters can be applied at a project-level to assess the value of trees for consideration in the project design phase. Design engineers for solar farms will be able to use tree retention values assigned to the respective tree categories to guide the solar farm layout.

2.0 Habitat Connectivity

Remnant patches of native vegetation in a heavily fragmented landscape provide crucial ecological functions (Law *et al.,* 2000; Carruthers *et al.,* 2004; Gibbons & Boak, 2002; Doerr *et al.,* 2010). The value of a patch accrues when fauna in the landscape use the patches to bring about connectivity (Beier & Noss, 1998). Connectivity in turn is relative to species dispersal ability and the characteristics of the inter-patch zone (‘the matrix’) (Fischer & Lindenmayer, 2007).

Structural connectivity of vegetation, i.e. areas with no gaps that significantly impede on fauna movement, is strongly correlated to species dispersal across landscapes (Beier & Noss, 1998; Doerr *et al*., 2010). Linear corridors have a high structural connectivity thereby providing a higher connectivity across a landscape compared to scattered trees. Discontinuous corridors were found to provide medium habitat value, where width was strongly correlated to occupancy (Doerr *et al*., 2010). Large, scattered trees provide “stepping stones” between these discontinuous corridors or patches of vegetation.

Connectivity also varies across landscapes. Patches within an urban landscape have a lower connectivity due to the higher resistance of the matrix. That is, fauna species have a lower dispersal threshold across urban areas compared to those in an agricultural landscape (e.g Baum *et al.,* 2004; Fischer & Lindenmayer, 2002; Hanspach *et al.,* 2012). Landscape connectivity may or may not accurately reflect connectivity for individual species. The ability of trees and patches to contribute to connectivity varies dependent on species characteristics (Forman, 1995; Beiyer & Noss, 1998). Corridors and stepping stones contribute to landscape connectivity but this might not be the case for all native species (Beier & Noss, 1998). As such, habitat connectivity can be assessed so that it represents the connectedness of patches of suitable habitat for a specific species or suite of species (Keitt *et al.,* 1997; Fisher & Lindenmayer 2007). This species-orientated approach requires considerable ecological input (dispersal thresholds, habitat selectiveness etc.), and must be supported by empirical evidence for it to be accurate (Radford *et al.,* 2005; Fischer & Lindenmayer, 2007).

Ecological connectedness can be measured by mathematical equations that allow for a quantitative assessment and can subsequently be used to produce connectivity maps (refer Figure 1 (a)). For example 'Graph Theory' has been successfully applied (e.g Keitt *et al.*, 1997; Van Langevelde, 2000; Rayfield *et al.,* 2011), whereby all patches are represented by a vertex. All vertices are connected by edges and reflect the distance between patches. This is suitable for application at a landscape scale and can be applied to different species dispersal thresholds to determine connectivity values of patches. The resulting graph would demonstrate the functional connectivity of a landscape.

Ecological connectivity can also be represented by more complex models that include network analysis or circuit analysis (Brandes & Erlebach, 2005). Network analysis considers the least-cost links between patches and can incorporate additional ecological characteristics of patches by assigning weights (Rayfield *et al.,* 2011; Liu *et al.*, 2018) (refer Figure 1 (b)). Circuit theory quantifies connectivity that responds positively to the presence of alternative pathways, connecting patches with multiple links (McRay, 2006; Braaker *et al.*, 2014) (refer Figure 1 (c)).

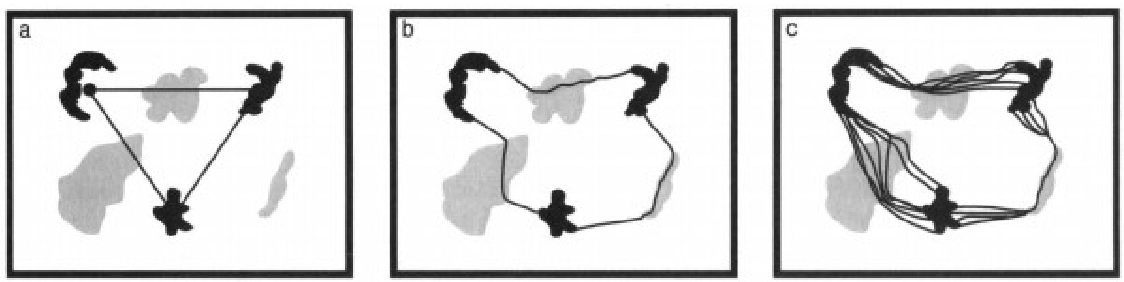

Figure 1 Methods of assessing habitat connectivity (sourced from Ray et al., 2011)

Representations of habitat connectivity that differ with respect to the amount of ecological information that they incorporate. Habitat patches (black polygons) are connected by links (black lines) that cross hospitable (grey) and inhospitable (white) matrix cover types. (a) A habitat graph connects patch centroids without incorporating a lot of spatial and ecological information about nodes and links. (b) A habitat network connects patch edges by least-cost links that incorporate information about matrix heterogeneity. Additional node and link attributes may also be included by assigning weights. (c) A habitat circuit connects patches with multiple links, thereby incorporating additional spatial information about the matrix.

3.0 Measuring Connectedness

Distance between trees and canopy cover are commonly used measures within habitat connectivity value assessments. Research is often focussed on demonstrating and defining the relationship of distance between trees and density of trees (i.e. canopy cover) to species richness and use of habitat. This section focusses on studies that incorporate a similar suite of species that are relevant to Victoria, including arboreal mammals, woodland birds, and bats.

The relationship of woodland bird species and patch size have been studied in Victoria, New South Wales and South Australia, all with similar outcomes. Fischer & Lindenmayer (2002) conducted empirical studies of bird use of paddock trees and remnant vegetation patches in New South Wales. Woodland birds were more likely to be found in remnant patches, whilst nectivores were more likely to be detected in trees more than 200 m from remnant patches. Open country species were correlated to larger isolated trees more than 200 m from the nearest woodland. The study demonstrated that both paddock trees and remnant patches of various sizes have a role to play in providing suitable woodland bird habitat.

Carruthers *et al.* (2004) investigated bird diversity and habitat preference in relation to canopy density in paddocks. Their findings found that 42 of the 45 species recorded in remnant vegetation were also observed in paddock trees. Diversity and abundance were correlated with tree density, however the study recognised the importance of isolated trees to wider species' habitat. Bird use of paddock trees were used by many birds, however their presence did not indicate how the tree was contributing to the value of the species' habitat.

Bennett & Ford (1997) looked at the relationship of woodland bird diversity by building a predictive model of populations relative to habitat availability, rainfall and temperature. The findings of the analysis suggested that at least 10% tree cover is required to maintain connectivity (Bennett & Ford, 1997). This is supported by Radford *et al.* (2005) who concluded that the distance of patches in a landscape was strongly correlated to species diversity within a patch. A threshold of species richness was identified where a significant reduction in species richness was observed in landscapes with less than 10% foliage cover. As a threshold level, anything below 10% would denote species extinction events (locally), therefore areas would need to support a higher habitat foliage cover to maintain viable populations.

The ability for sedentary woodland bird species to disperse was documented in Doerr *et al.* (2011). They determined functional connectivity to consist of trees no more than 200 m apart and larger remnant patches of no more than 2 km apart. The strength of this study lies in the catering for a bird species (commonly highly mobile) with the lowest dispersal range. The thresholds would therefore be applicable to a wider variety of more mobile species.

A study conducted by Le Roux *et al.* (2018) looked at the abundance of species, diversity, and community composition at isolated trees and how these varied in different landscapes (urban, agricultural etc) and the size of the tree. Their results were surprising, with no correlation between tree size with bat and trunk arthropods, yet a strong correlation with bird communities (refer Figure 2). This demonstrates that even small trees contribute to overall habitat complexity with the landscape.

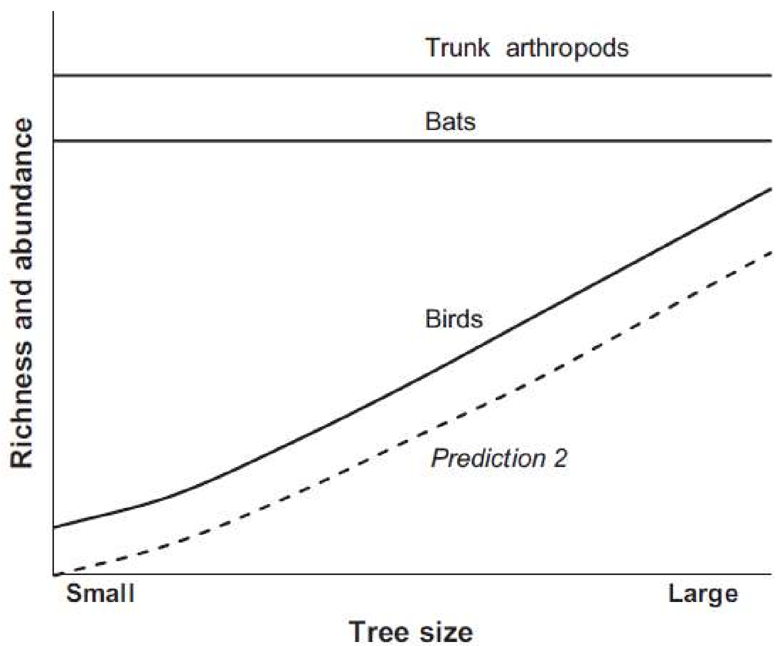

Figure 2 Relationship of tree size, trunk arthropods, bats and birds (Le Roux *et al.*, 2018)

The likelihood of occupancy of paddock trees by nocturnal mammals was investigated by Law *et al.* (2000). Their study found that both distance to and size of the nearest patch was strongly correlated to the likelihood of occupancy. Trees less than 800 m from remnant State Forest (>10 ha in size) significantly increased the likelihood of occupancy by nocturnal mammals. However, trees less than 800 m from an area smaller than 10 ha did not affect the probability of occupancy by nocturnal mammals. These types of studies are useful in providing the necessary ecological information to develop robust models of habitat use.

Bat activity in relation to scattered trees (<1 tree per ha) versus woodland blocks (>35 trees per ha) was investigated by Lumsden & Bennett (2004). Overall increased activity was shown to correspond with the category of dense scattered trees rather than the woodland blocks. Peak level of bat activity was found to be at 20-30 trees per ha. This can be partially attributed to optimal foraging opportunities which require sufficient space between trees for less-manoeuvrable species. Whilst it is improbable that a single scattered tree will provide all the resources necessary, the mobility of bats allows them to exploit multiple patches of habitat using these scattered trees.

Gliding marsupials (*Petaurus* spp.) and their use of isolated trees and small patches was studied by van der Ree *et al*., (2004). The threshold for this species was defined at 75 m, with 95% of species occurring in smaller patches and isolated trees that were within this threshold to the larger linear network in the landscape. This also corresponds with the maximum distance that they can glide through trees in a single movement.

As more studies are being conducted, and more information becomes available, it has become apparent that assessing habitat value is complex. Studies have shown that scattered trees, for example, provide disproportionate habitat benefits for biota relative to their size and availability (Carruthers *et al*., 2004; Le Roux et al, 2018). In areas where the smaller patches represent a significant proportion of the total foliage cover, the need for protection is even greater (Carruthers *et al.,* 2004; Gibbson & Boak, 2002). This demonstrates that previous notions of value may not be valid in heavily fragmented landscapes.

4.0 Scattered Tree Policies in Australia

The importance, level of protection and value assessment of scattered trees differs considerably across Australian States. This is not surprising considering the vast differences in land use, climate, and ecological value of the different States.

Western Australia (WA) offers no protection for scattered trees therefore no method for assessing trees is prescribed. WA legislation focusses on protecting threatened species habitat with little regard for maintaining connectivity. For scattered trees this means that unless they are in the modelled habitat for any of the three threatened Black Cockatoo species (Forest Red-tail *Calyptorhynchus banksii naso*, Carnaby *Calyptorhynchus latirostris* and/or Baudin's Black Cockatoo *Calyptorhynchus baudinii*), it is offered no level of protection. A Black Cockatoo habitat assessment would only consider trees with a diameter at breast height (DBH) of 50 cm or higher. It should be noted that Black Cockatoo habitat extends across the majority of southwest WA which is the area most affected by habitat fragmentation and clearing. Further to this, the vegetation clearing policy includes an exemption for landowners for clearing up to 5 ha per year.

Northern Territory (NT), similar to WA, offers no protection for scattered trees and no method for assessing trees or their value is prescribed. Clearing less than 1 ha of native vegetation is exempt from a clearing permit unless within particular 'zones' of land.

Victoria has a comprehensive framework for assessing all native vegetation including scattered trees. There are three pathways under which an application to remove native vegetation can be assessed; Basic, Intermediate or Detailed. The clearing of one or more large trees requires, as a minimum, an Intermediate level of assessment. Currently the assessment comprises the recording of all trees and their location, with no assessment of 'value' per se. The value of paddock trees and their method of assessment has recently been a source of contention in some local councils. Particularly when the Victorian Civil and Administrative Tribunal prevented a farmer from clearing 23 paddock trees enabling the farmer to improve agriculture outputs (Cullen, 2019). This case reflects local councils recognition of the importance of retaining scattered trees.

In New South Wales (NSW) clearing of scattered trees has been declared by the Minister for the Environment to be a routine agricultural management activity. Landowners can self-asses the requirement for clearing scattered trees without requiring a property vegetation plan (PVP) as outlined in relevant guidelines. Under these guidelines, scattered trees can be cleared without a permit (however the Local Land Services must be notified), if a tree falls into one of the following criteria:

- if it is an individual tree less than 80 cm DBH and is either located more than 50 m from the nearest living tree with a DBH greater than 20 cm <u>or</u>
- as part of a group of three or less trees within a distance of 50 m of one another that is more than 50 m from the next living tree with DBH greater than 20 cm.

South Australia (SA) have implemented a detailed quantitative method for assessing the value of scattered trees. The SA Scattered Tree Assessment Manual (NVC, 2017) describes a scoring system applicable to all trees. The method was derived from two studies conducted by Carruthers *et al.*, (2004) and Cutten & Hodder (2002).

Table 1 Scattered tree scoring system applicable in South Australia (NVC, 2017)

Attribute	Low Value (1 points)	Medium Value (2points)	High Value (3points)
Height Measured in metres	See (ii) Height above or refer to Appendix 5 & 7	See (ii) Height above or refer to Appendix 6 & 7	See (ii) Height above or refer to Appendix 6 & 7
Diameter Measured in centimetres at 1 m above the ground	Less than 20cm	20cm or more but less than 50cm	50cm or more
Health Based on % foliage dieback	Enter % Dieback for each tree		(Excel formula calculates the score)
Hollow entrances Small - 5cm or less diameter Medium > 5cm to <15cm Large 15cm or more	No hollows visible = 1 point	1-4 small or 1 medium visible	5+ small; 2+ medium; 1+ large; or 1-4 small and 1 medium visible
Suitability for threatened species For feeding, roosting, nesting, shelter etc	None (Common only)	1 Uncommon species (at regional, state or national level)	At least 2 Uncommon, or 1 or more Rare species (at regional, state or national level)
Density (i.e. distance to nearest neighbours) Distances measured from tree canopy edge to the nearest other tree canopy edge (Only consider plants 2 or more metres in height)	Widely separated • Tree more than 50 metres away from all other trees; or • Two trees less than 50m apart, but each more than 50m away from all other trees	Mid-densely separated • 3 or more trees each within 5 to 50m of at least 1 other tree in the group; or • Two trees less than 5m apart, with at least one being within 5 to 50m of at least one other tree	Close • 3 or more trees each within 5 metres of at least 1 other tree in the group
Proximity to native vegetation Distance from tree to block of native vegetation at least 1 hectare in area	200 metres or more from a block of native vegetation	Between 50 and 200m from a block of native vegetation	Within 50m of a block of native vegetation

5.0 Tree Assessment Method

Assessment of tree value has been designed based on one or more of the following components:

- **Threatened species utilisation assessment** – based on arbitrary assumptions on dispersal of threatened species that may utilise the area and proximity to 'core habitat' (e.g. Wood, 2016; NVC, 2017);
- **Total foliage cover** of a given patch – enables set criteria to be applied e.g. foliage cover not to reduce below 10% (determined as the critical threshold for species by Bennett & Ford, 1997). and Radford *et al.* (2005); and
- **Habitat complexity** – trees within proximity to one another, distance to waterbodies, rivers, corridors, remnant patches, elevation in landscape etc. (demonstrated by Law *et al*., 2000 and utilised in NVC, 2017).

An effective assessment method must consider local conditions, including fauna species occupation, their dispersal threshold, extent of habitat fragmentation in the landscape, and habitat features present in the local area. Ideally the assessment of tree value would be quantifiable and justifiable without being unnecessarily onerous or significantly increase resources required to complete the task. Ideally the process would utilise data already captured as part of ecological surveys.

Utilising information gained from the literature review in Section 2.0 and 3.0, spatial parameters have been developed to categorise Large Trees in Patches (LTP) and Large Scattered Trees (LSTs) based on their level of connectedness (i.e. Cat 1 = greater connectivity and Cat 3 = less connectivity). Spatial parameters were analysed using GIS-based tools to determine the tree retention category.

A set of tree retention rules have been developed for each spatial category to guide solar grid layout. LTPs and more connected LSTs provide increased habitat complexity and are desirable to a range of fauna species. Isolated trees also provide habitat value, but to fewer fauna groups.

Table 2 categorises LSTs and LTPs distance thresholds for various fauna groups along with a description of how to undertake the spatial analysis. Table 2 also lists the tree retention rules that have been developed to guide solar engineers to design solar farm layouts.

Table 2 Categories of trees as defined by specific spatial parameters and retention values.

Category	Description	Implementation	Retention rules	Rational
1	All remnant patches containing a canopy component within Habitat Hectare Assessment.	1. Identify all patches that have a value in the tree canopy component as informed by the Habitat Hectare score sheet.	Retain Category 1 trees.	Suitable habitat for bat species. Increased habitat complexity desirable for a range of fauna species.
2	Large Scattered Trees (LST) within 75 m of a remnant patch, two or more LST or other habitat feature(s).	1. Identify all patches that have a value in the tree canopy component as informed by the Habitat Hectare score sheet. Also identify other habitat features that occur within and adjacent to the assessment area including waterways and waterbodies. 2. Use this to conduct a proximity analysis of LST within 75m of habitat features and other LSTs.	Retain Category 2 trees.	75 m is the threshold for gliding marsupials.
3	LST >75 m from other LST or habitat feature and, is not in Category 2.	1. Identify all patches that have a value in the tree canopy component as informed by the Habitat Hectare score sheet. 2. Also identify other habitat features that occur within and adjacent to the assessment area including waterways and waterbodies. Use this to conduct a proximity analysis of LST greater than 75m of habitat features and other LSTs.	Retain up to 30% of Category 3 (trees >75 m from other LST or habitat features).	Suitable for woodland bird species. Less than 10% foliage cover in a landscape would result in a significant reduction in species richness.

Rules: Where a tree occurs within more than one category, assign tree to highest category.

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