

## Great Western Woodlands Project



### Overview

Fire is a recurrent disturbance across Mediterranean-climate landscapes. Fire shapes vegetation patterns, community composition and community diversity. Understanding how communities change with aspects of the fire regime, such as time since fire, is crucial for the identification of appropriate fire return intervals for biodiversity conservation.

The [Great Western Woodlands](#) (GWW) is an internationally significant area with great biological and cultural richness. This 16 million ha region of south-western Australia arguably comprises the largest and most intact area of contiguous temperate woodland remaining on Earth. The woodlands of the GWW are typically fire sensitive and are at risk from inappropriate fire regimes.



### Project Aims

The project addresses fire ecology and management in the GWW, by using space-for-time surveys to investigate the effects of time since fire on [assembly and recovery of plant community composition](#), development of ecosystem structure, and fuel dynamics. These components of the project are ongoing, with a journal paper on assembly and recovery of plant community composition under review. The 'Fire in Gimlet woodlands' webpages will be updated with this new information when it becomes available.

A key component of the research has been the development of methods to [estimate the time since fire of long-unburnt vegetation](#).

The research will deliver critical information for the ecological management of fire in the GWW.

### Study location

The GWW are located in south-western Australia, between the largely cleared wheatbelt to the west and arid rangelands to the east and north. Our study was conducted in the [western portion of the GWW](#).



### Methods

We identified woodlands dominated by gimlet (*Eucalyptus salubris*) as being an important community to investigate the effects of time since fire on vegetation composition. Gimlet is a tree killed by complete canopy scorch and is a dominant canopy species in woodlands across the breadth of the GWW. Please follow the links for full details on how [plot time since fire was determined](#) and how [vegetation composition and soil characteristics](#) were measured.

### Resources and publications

Follow these links for access to [project data](#), [metadata](#) and [resources and publications](#).

### Contacts, project team and recommended citation

Click [here](#) for further details.



### Acknowledgements

This project was jointly supported by the Department of Environment and Conservation's (DEC) [Great Western Woodlands Conservation Strategy](#), CSIRO Ecosystem Sciences (CES) and the Australian Supersite Network, part of the Australian Government's [Terrestrial Ecosystems Research Network](#), a research infrastructure facility established under the National Collaborative Research Infrastructure Strategy and Education Infrastructure Fund - Super Science Initiative - through the Department of Industry, Innovation, Science, Research and Tertiary Education. Georg Wiehl (CES), Paul Gioia, Aminya Ennis, Lachie McCaw and Glen Daniel (all DEC) contributed to various aspects of the project.

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### Estimating the time since fire of long-unburnt *Eucalyptus salubris* plots - Methods

The full details of the methods, results and management implications of this research can be found in [Gosper et al. \(2013\)](#), but the methods are briefly summarized here.

#### Aims

Establishing the time since disturbance is a significant challenge in infrequently-disturbed communities. We aimed to characterise the relationship between observable tree rings, plant age and plant size in *Eucalyptus salubris*, to extend the ability to determine the time since fire of woodland stands beyond that available from satellite imagery. We then estimated the age of long-unburnt *E. salubris* stands and the age class distribution of *Eucalyptus* woodlands more broadly.

#### Study location

*Eucalyptus salubris* woodlands in semi-arid Mediterranean climate south-western Australia, in the [western parts of the Great Western Woodlands](#) in the districts of Karroun Hill (30°14'S, 118°30'E), Yellowdine (31°17'S, 119°39'E) and Parker Range (31°47'S, 119°37'E).



#### Plot selection

In each district, 50 m x 50 m plots were placed in relatively uniform *E. salubris* woodland in each of the following time since fire age classes: < 10 years (4-8 plots per district), 38-60 years (3-5 plots per district) and long-unburnt (> 60 years; 11-13 plots per district). An additional 3 plots 10-38 years post-fire were sampled where such fires had occurred, giving a total of 72 plots.

#### Determining time since fire of sample plots

At each plot we sampled 16 trees by use of a modified version of the point-centred quarter method, measuring the diameter at the base of trunks ( $D_{10}$ ) and plant height of the nearest tree in each of the four compass quadrants radiating from the four corners of each plot. At 39 of the 72 sites, we randomly selected three individual *E. salubris*, and measured plant height and diameter at their base ( $D_{10}$ ). We then took either a basal trunk section using a hacksaw ( $n = 100$  trees, 34 sites; sanded prior to scoring for growth rings) or a 12 mm diameter core using a motorised tree corer ( $n = 17$  trees, seven sites; two sites has a combination of sections and cores), depending on plant size. As nearly all trees sufficiently large as to require coring were hollow, only sections were used in analyses.

Regression analyses were used to test for relationships between:

1. plant age (assumed to be equal to plot time since fire, as determined from Landsat imagery for plots burnt since 1972) and mean number of growth rings per trunk. Linear relationships were strong and positive, indicating growth rings can be used to estimate plant time since fire;
2. mean number of growth rings per trunk and various combinations of plant size (plant diameter at the base and/or plant height) and plot location. For relationships between ring count and plant size and location variables, linear models were tested on untransformed, and square-root and  $\log_{10}$  transformed ring counts, to test if plant growth rate declined with plant age. Models were compared on the basis of maximising adjusted  $r^2$  and (within transformation alternatives) minimizing AIC (Akaike information criterion). Plant height reached a plateau shortly beyond the tallest trees with a complete growth ring record, indicating that tree height was likely to be a poor predictor of growth rings in old trees. The best performing plausible models were: (1) untransformed growth rings predicted by tree diameter + location; and (2) square-root growth rings predicted by tree diameter + location. These are the two models used for generating alternative time since fire estimates for long-unburnt plots.

The effectiveness of the models in estimating growth rings was tested using the plant size data from the point-centred quarter measurements, using all 23 plots of known age (burnt after 1972). Pearson's correlation coefficient indicated a moderately strong correlation between known age and estimated age from the best-performing models.

Plant size data from the point-centred quarter measurements was used at plots not burnt since 1972 and without a complete growth ring record to estimate their time since fire. The two best-performing plausible models produced large differences in estimated plot times since fire of the longest-unburnt plots (with the model of untransformed growth rings (Model 2) producing much lower estimates (range 88-370 years) than the model of square-root transformed growth rings (Model 5; range 110-1460 years)), with uncertainty in time since fire estimates increasing especially beyond 200 years post-fire.



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### Plant diversity in fire-sensitive temperate eucalypt woodlands - Methods

The full details of the methods, results and management implications of this research will be available in a journal publication shortly, but are briefly summarized here.

#### Aim

To better understand the impacts of time since fire on plant composition and diversity in fire-sensitive eucalypt woodlands, using a space-for-time approach.

#### Study location

*Eucalyptus salubris* woodlands in semi-arid Mediterranean climate south-western Australia, in the [western parts of the Great Western Woodlands](#) near Karroun Hill (30°14'S, 118°30'E), Yellowdine (31°17'S, 119°39'E) and Parker Range (31°47'S, 119°37'E).

#### Plot selection

Each of the 72 plots was 50 x 50 m (unless as noted on [sites table](#)), with sides aligned north-south and east-west and with a steel dropper placed in the north-west corner. Plots were placed in relatively uniform vegetation within 1 km of vehicular tracks on public land; Nature Reserves, Unallocated Crown Land or Unmanaged Reserves. Plots were spaced at least 250 m apart, and at least 500 m apart for plots of the same time since fire. Plot location was taken with a GPS. Plot times since fire were determined using a combination of Landsat imagery, growth ring counts and growth ring-plant size relationships. The time since fire range of samples was 3-370 years (using Model 2 of [Gosper et al. \(2013\)](#); using an equally valid alternative model for estimating time since fire this range was 3-1460 years; Gosper et al. (2013)).

#### Flora sampling

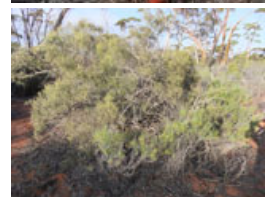
In each plot we recorded the vascular plant taxa present by tallying all species detected in nested plots of 1, 5, 10, 25, 100, 500, 1000 and 2500 m<sup>2</sup>. Abundance was estimated by systematically placing a 12.5 mm diameter pole vertically at 50 points per plot, each 3 m apart, and recording the identity of all plants with live parts intercepting the pole. Sixteen of these points were placed along each of the two sides of the 50 x 50 m plot commencing at the north-west corner, with the remaining 18 points placed along the diagonal starting in the same corner. This technique provided an objective measure of abundance reflecting but not equivalent to projective cover. Species that were present but not recorded at point intercepts were allocated a nominal proportional abundance of 1%.

#### Diversity indices

[Diversity indices](#) were calculated per plot. We tallied total species number per plot (species density), and using cover data, calculated the Shannon diversity index ( $\log_e x$ ) and Pielou's evenness index.

#### Soil sampling

A single bulked sample of the top 10 cm of soil was taken from aggregation of multiple 2 cm diameter sub-samples collected from a subset of 52 plots. Samples were stored at ~4°C until delivery to the CSBP Futurefarm analytical laboratories (Bibra Lake, WA), where they were thoroughly mixed, air dried at 40°C, and ground to pass through a 2 mm sieve. [Analyses](#) were undertaken on each bulked sample to determine available phosphorus, potassium, ammonium, nitrate, organic carbon, extractable sulphur, pH (CaCl<sub>2</sub>) and conductivity.



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### Data downloads

Two data files are available for download, in Microsoft Excel format. [Metadata](#) associated with this information is available. These data are currently being used for research into the impacts of fires on *Eucalyptus salubris* woodlands. These data have been used to support one journal [publication](#), with a second under review at present. While these data are freely available for use, we request that potential users contact the project team to discuss opportunities for collaboration. Note that some of these data are duplicates of data available at the [TERN Data Discovery Portal](#), lodged under the project "[Time-since-fire plots. Great Western Woodlands \(1\) Floristic composition and diversity](#)".

1. A [table](#) listing the plots sampled, their location, their estimated time since fire and the sample data collected at each.
2. A [table](#) containing data on plot diversity indices, species-area relationships, floristic cover and soil nutrient composition.
3. A representative photo from each plot is below. Note that all photos are copyright 'Carl Gosper and Georg Wiehl, Department of Environment and Conservation and CSIRO Ecosystem Sciences'



### Site photos

Click on each site number for a site photograph. All photos are copyright 'Carl Gosper and Georg Wiehl, Department of Environment and Conservation and CSIRO Ecosystem Sciences.'

[GIM01](#) [GIM02](#) [GIM03](#) [GIM04](#)

[GIM05](#) [GIM06](#) [GIM07](#) [GIM08](#)

[GIM09](#) [GIM10](#) [GIM11](#) [GIM12](#)

[GIM13](#) [GIM14](#) [GIM15](#) [GIM16](#)

[GIM17](#) [GIM18](#) [GIM19](#) [GIM20](#)

[GIM21](#) [GIM22](#) [GIM23](#) [GIM24](#)

[GIM25](#) [GIM26](#) [GIM27](#) [GIM28](#)

[GIM29](#) [GIM30](#) [GIM31](#) [GIM32](#)

[GIM33](#) [GIM34](#) [GIM35](#) [GIM36](#)

[GIM37](#) [GIM38](#) [GIM39](#) [GIM40](#)

[GIM41](#) [GIM42](#) [GIM43](#) [GIM44](#)

[GIM45](#) [GIM46](#) [GIM47](#) [GIM48](#)

[GIM49](#) [GIM50](#) [GIM51](#) [GIM52](#)

[GIM53](#) [GIM54](#) [GIM55](#) [GIM56](#)

[GIM57](#) [GIM58](#) [GIM59](#) [GIM60](#)

[GIM61](#) [GIM62](#) [GIM63](#) [GIM64](#)

[GIM65](#) [GIM66](#) [GIM67](#) [GIM68](#)

[GIM69](#) [GIM70](#) [GIM71](#) [GIM72](#)



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### Resources and publications

The following publications describe the results, outcomes and management implications of the project. Additional publications will be added as they become available. Some publications are downloadable as PDFs, others have links to websites hosting the publication.

#### Estimating the time since fire of gimlet woodlands

##### Journal paper

This contains the technical details of the research and has undergone peer-review.

Gosper, C.R., Prober, S.M., Yates, C.J. and Wiehl, G. (2013) Estimating the time since fire of long-unburnt *Eucalyptus salubris* (Myrtaceae) stands in the Great Western Woodlands. Australian Journal of Botany 61, 11-21. [doi: 10.1071/BT12212](https://doi.org/10.1071/BT12212)

##### DEC Science Division Information Sheet

This provides a 2-page summary of the key findings and management implications of our research.

Gosper, C., Yates, C. and Prober, S. (2013) Ageing long-unburnt gimlet woodlands. [Science Division Information Sheet 65/2013](#).

**Information Sheet 65/2013**  
Science Division

**Ageing long-unburnt Gimlet woodlands**  
by Carl Gosper, Cath Haber, Suzanne Prober and Cheryl Wiehl  
DEC Science Division, 11/2013 (Supersedes Science, 04/12/2014)  
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**Background**

Establishing the time since disturbance is a significant challenge in studies of temporal changes in ecosystem composition and function in infrequently-disturbed communities. Individual fire events, for example, can have effects lasting for centuries. Dating fires that occurred prior to those documented in contemporary sources (e.g. historical records or remote-sensed imagery) is not a trivial problem, as many ecological processes, such as hollow formation, operate over long time scales. Estimates of the actual time since fire of long-unburnt vegetation can be made through dendrochronology (measuring trunk growth rings), or establishing relationships between plant size and time since fire.

*Eucalyptus salubris* (gimlet) is a fire-intolerant tree widespread across the globally-significant Great Western Woodlands (GWW). We aimed to characterise the relationship between gimlet tree rings, plant age and plant size. The woodlands of the GWW are typically fire sensitive and are at risk from inappropriate fire regimes. Uncertainty concerning the time since fire of long-unburnt woodlands, and hence the scale over which temporal changes in woodland dynamics occur, currently constrains understanding as to whether the recent fire regime represents a significant long-term threat to mature woodland ecosystems.

**Findings**

- Growth ring counts strongly reflected plant time since fire over the period for which fires could be dated with certainty (the last 40 years). Growth rings could be used to estimate the time since fire of plants up to approximately 100 years old, by which time most gimlets had developed hollow cores, truncating the growth ring records.
- A variety of models were tested to estimate the number of growth rings, incorporating a variety of combinations of predictors (tree diameter at the base, height and location) and transformations. Models based on both untransformed and square-root transformed growth rings predicted by tree diameter (a location) performed well over the range of trunk diameters that could be dated (Figure 1). These models could be used to estimate stand time since fire.
- For trunks >20 cm diameter, there is greater uncertainty over their time since fire (Figure 1).



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### Metadata

#### Title

Fire regimes and effects of fire in gimlet (*Eucalyptus salubris*) woodlands

#### Abstract

Disturbances are important ecosystem processes affecting patterns of species diversity (including species richness, diversity and evenness) and community composition. Determining appropriate disturbance regimes for particular ecosystems is thus an important issue for natural resource management. There have been few studies of the response of plant species composition and diversity to fire in 'fire-sensitive' Mediterranean-climate woodlands, where the dominant overstorey trees are typically killed by fire, resulting in dense post-fire recruitment. The Great Western Woodlands (GWW) region of south-western Australia supports the world's largest remaining area of Mediterranean-climate woodland, which in mosaic with mallee, shrublands and salt lakes cover an area of 160 000 km<sup>2</sup>. *Eucalyptus* woodlands in this region are typically fire-sensitive, and fire return intervals recorded over recent decades have been much shorter than the long-term average. This has led to considerable conservation concern regarding the loss of mature woodlands, and has highlighted a need to better understand how plant species composition and diversity changes with time since fire. We established a series of plots in gimlet woodlands within the Great Western Woodlands [TERN Supersite](#) at a range of times since fire (72 50 x 50 m plots). To estimate plot ages for this study we used satellite imagery, growth ring counts and relationships between growth ring counts and plant size.

#### Keywords

Ecological fire management; fire interval; Mediterranean-type ecosystem; obligate seeder; space-for-time; succession

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#### Funding Sources

1. A biodiversity and cultural conservation strategy for the [Great Western Woodlands](#), Western Australian Department of Environment and Conservation
2. Australian Supersite Network, part of the Australian Government's [Terrestrial Ecosystems Research Network](#), a research infrastructure facility established under the National Collaborative Research Infrastructure Strategy and Education Infrastructure Fund - Super Science Initiative - through the Department of Industry, Innovation, Science, Research and Tertiary Education.

#### Usage Rights

These data are currently being used for research into the impacts of fires on *Eucalyptus salubris* woodlands. These data have been used to support one journal [publication](#), with a second under review at present. These data are freely available for use, however, we request that potential users contact the project team to discuss opportunities for collaboration. Note that some of these data are duplicates of data available at the [TERN Data Discovery Portal](#), lodged under the project "[Time-since-fire plots. Great Western Woodlands \(1\) Floristic composition and diversity](#)".

#### Geographic coverage

The [western half of the Great Western Woodlands](#), south-western Western Australia. Plots were established in the vicinities of Karroun Hill (30°14'S, 118°30'E); Yellowdine (31°17'S, 119°39'E) and Parker Range (31°47'S, 119°37'E).

#### Temporal coverage

1 July 2010 to 1 December 2012

#### Taxonomic coverage

All vascular flora. Taxonomy follows [Florabase](#), Western Australian Herbarium (1998-2012) as at 4 January 2011.



## Methods

See links for methods for [estimating the time since fire of \*E. salubris\* plots](#) and [measuring floristic diversity](#).

## Description of columns in data files

### 1. [Plot details table](#)

| Column Header            | Descriptor  |
|--------------------------|---|
| Plot number              |   |
| Datum                    |   |
| Zone                     | UTM   |
| Easting                  | NB - in text format to preserve 0   |
| Northing                 |   |
| Latitude                 |   |
| Longitude                |   |
| Location accuracy        |   |
| Elevation                | Metres above sea level (measured with GPS)  |
| Aspect                   |   |
| Topo position            | Topographic position  |
| Location                 | Written description of plot location  |
| Tenure                   | UCL = Unallocated Crown land; NR = Nature Reserve   |
| Date established         | Same as date plot sampled for flora   |
| Vegetation               | Lists dominant canopy species   |
| Surface soil description | Written description   |
| Soil_sample              | Sample number   |
| Photos                   | Y = Yes for plot photo(s)   |
| Species-area             | Y = Yes for species-area data (nested subplots within 50 x 50 m)  |
| Flora_richness           | Y = Yes for species density determined per 2500 m <sup>2</sup> plot   |
| Flora_cover              | Y = Yes for floristic cover measured  |
| Veg_structure            | Y = Yes for vegetation structure measured   |
| Fuel                     | Y = Yes for VESTA fuel assessment conducted   |
| LS Fire year             | Year of fire from Landsat image analysis  |
| LS Yrs since fire        | Years since fire from Landsat image analysis (i.e. time since fire truncated at 60 years for plots with no evidence of fire in the oldest (1972) Landsat image).  |
| Model 2 fire date        | Year of fire (= number of growing seasons post-fire, not necessarily calendar year) of plots from Landsat image analysis, estimates from growth ring counts, and growth ring-size relationships using Model 2 of <a href="#">Gosper et al. (2013)</a> . Model 2 and Model 5 were the best-fitting plausible models. |
| Model 2 yrs since fire   | Years since fire (growth seasons) from estimates from Landsat image analysis, growth ring counts and growth ring-size relationships using Model 2 of <a href="#">Gosper et al. (2013)</a> .   |
| Model 5 fire date        | Year of fire (= number of growing seasons post-fire, not necessarily calendar year) of plots from Landsat image analysis, estimates from growth ring counts, and growth ring-size relationships using Model 5 of <a href="#">Gosper et al. (2013)</a> . Model 2 and Model 5 were the best-fitting plausible models. |
| Model 5 yrs since fire   | Years since fire (growth seasons) from estimates from Landsat image analysis, growth ring counts and growth ring-size relationships using Model 5 of <a href="#">Gosper et al. (2013)</a> .   |
| Dating method            | Method used for determining 'Model 2 (or 5) yrs since fire': L = Landsat, R = growth ring count, E = estimate from growth ring-size relationships   |
| Notes                    |   |

### 2. [Diversity-floristics table](#): Diversity indices worksheet

| Column Header   | Descriptor  |
|-----------------|---|
| Plot            | Plot number. NB - All indices per 2500 m <sup>2</sup> area            |
| Species_density | Number of species per plot  |
| Evenness        | Pielou's evenness calculated on cover data                            |
| Diversity       | Shannon diversity index (log <sub>e</sub> x) calculated on cover data |

### 3. [Diversity-floristics table](#): Species-area worksheet

| Column Header      | Descriptor                                    |
|--------------------|---|
| Plot               | Plot number                                   |
| 1 m <sup>2</sup>   | Cumulative number of species per subplot area |
| 5m <sup>2</sup>    | Cumulative number of species per subplot area |
| 10m <sup>2</sup>   | Cumulative number of species per subplot area |
| 25m <sup>2</sup>   | Cumulative number of species per subplot area |
| 100m <sup>2</sup>  | Cumulative number of species per subplot area |
| 500m <sup>2</sup>  | Cumulative number of species per subplot area |
| 1000m <sup>2</sup> | Cumulative number of species per subplot area |
| 2500m <sup>2</sup> | Cumulative number of species per plot area    |

### 4. [Diversity-floristics table](#): Floristic cover worksheet

| Column Header    | Descriptor   |
|------------------|--|
| Plot             | Plot number  |
| Acacia andrewsii | Cover of Acacia andrewsii (0 = absent, 1% = present but not recorded at point intercepts, 2% = recorded at 1 of 50 intercepts etc) |
| etc              |  |

5. [Diversity-floristics table](#): Soils data

| Column Header           | Descriptor (see methods)               |
|-------------------------|--|
| Plot_Number             |  |
| Ammonium                |  |
| Nitrate                 |  |
| P                       | Available phosphorus                   |
| K                       | Potassium                              |
| Sulphur                 | Extractable sulphur                    |
| Organic_C               | Organic carbon                         |
| Conductivity            | Conductivity (1:5 soil:water extract)  |
| pH (CaCl <sub>2</sub> ) | pH (1:5 soil/0.01M CaCl <sub>2</sub> ) |



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### Contact information

Please contact us for further information on any aspect of the study.

### Recommended citation

To cite the study methodology, please cite the relevant [publication\(s\)](#). Citation for the data:

Gosper CR, Yates CJ and Prober SM (2013). Fire in gimlet woodlands. NatureMap, Department of Environment and Conservation. On-line: <http://naturemap.dec.wa.gov.au/Query.aspx?querytype=content&content=gimlet>

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| Plot  | Species_density | Evenness | Diversity |
|-------|-----------------|----------|-----------|
| GIM01 | 18              | 0.522    | 1.509     |
| GIM02 | 42              | 0.6629   | 2.478     |
| GIM03 | 28              | 0.7673   | 2.557     |
| GIM04 | 23              | 0.728    | 2.283     |
| GIM05 | 26              | 0.7342   | 2.392     |
| GIM06 | 41              | 0.826    | 3.068     |
| GIM07 | 57              | 0.8756   | 3.54      |
| GIM08 | 53              | 0.8413   | 3.34      |
| GIM09 | 29              | 0.6924   | 2.331     |
| GIM10 | 21              | 0.678    | 2.064     |
| GIM11 | 43              | 0.8351   | 3.141     |
| GIM12 | 41              | 0.8278   | 3.074     |
| GIM13 | 42              | 0.7051   | 2.635     |
| GIM14 | 24              | 0.6957   | 2.211     |
| GIM15 | 27              | 0.7147   | 2.356     |
| GIM16 | 37              | 0.7056   | 2.548     |
| GIM17 | 40              | 0.7548   | 2.784     |
| GIM18 | 32              | 0.7713   | 2.673     |
| GIM19 | 50              | 0.8497   | 3.324     |
| GIM20 | 35              | 0.6966   | 2.477     |
| GIM21 | 49              | 0.7743   | 3.013     |
| GIM22 | 43              | 0.6931   | 2.607     |
| GIM23 | 27              | 0.6483   | 2.137     |
| GIM24 | 18              | 0.7141   | 2.064     |
| GIM25 | 37              | 0.8233   | 2.973     |
| GIM26 | 62              | 0.8228   | 3.396     |
| GIM27 | 41              | 0.8502   | 3.157     |
| GIM28 | 33              | 0.8865   | 3.1       |
| GIM29 | 40              | 0.7805   | 2.879     |
| GIM30 | 34              | 0.7779   | 2.743     |
| GIM31 | 27              | 0.6603   | 2.176     |
| GIM32 | 31              | 0.7399   | 2.541     |
| GIM33 | 28              | 0.7165   | 2.387     |
| GIM34 | 25              | 0.608    | 1.957     |
| GIM35 | 27              | 0.7632   | 2.515     |
| GIM36 | 32              | 0.7373   | 2.555     |
| GIM37 | 40              | 0.7477   | 2.758     |
| GIM38 | 32              | 0.7812   | 2.708     |
| GIM39 | 55              | 0.7393   | 2.963     |
| GIM40 | 44              | 0.7864   | 2.976     |
| GIM41 | 40              | 0.8038   | 2.965     |
| GIM42 | 34              | 0.7417   | 2.615     |
| GIM43 | 59              | 0.7385   | 3.011     |
| GIM44 | 33              | 0.6627   | 2.317     |
| GIM45 | 27              | 0.7407   | 2.441     |
| GIM46 | 52              | 0.8451   | 3.339     |
| GIM47 | 53              | 0.793    | 3.148     |
| GIM48 | 30              | 0.5569   | 1.894     |
| GIM49 | 20              | 0.7529   | 2.256     |



|       |    |        |       |
|-------|----|--------|-------|
| GIM50 | 36 | 0.849  | 3.042 |
| GIM51 | 41 | 0.7598 | 2.822 |
| GIM52 | 33 | 0.7661 | 2.679 |
| GIM53 | 46 | 0.6759 | 2.588 |
| GIM54 | 55 | 0.7189 | 2.881 |
| GIM55 | 49 | 0.7245 | 2.82  |
| GIM56 | 31 | 0.7851 | 2.696 |
| GIM57 | 56 | 0.8225 | 3.311 |
| GIM58 | 71 | 0.872  | 3.717 |
| GIM59 | 38 | 0.7228 | 2.629 |
| GIM60 | 28 | 0.6637 | 2.211 |
| GIM61 | 62 | 0.828  | 3.417 |
| GIM62 | 25 | 0.6761 | 2.176 |
| GIM63 | 49 | 0.8467 | 3.295 |
| GIM64 | 47 | 0.7162 | 2.757 |
| GIM65 | 36 | 0.8321 | 2.982 |
| GIM66 | 41 | 0.769  | 2.856 |
| GIM67 | 39 | 0.7924 | 2.903 |
| GIM68 | 24 | 0.8048 | 2.558 |
| GIM69 | 35 | 0.7995 | 2.842 |
| GIM70 | 61 | 0.9328 | 3.835 |
| GIM71 | 52 | 0.8842 | 3.494 |
| GIM72 | 31 | 0.8857 | 3.042 |

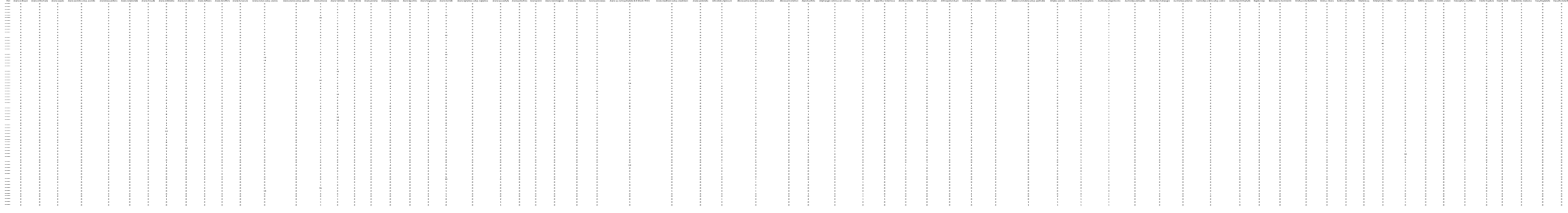
## Notes to accompany diversity indices spreadsheet

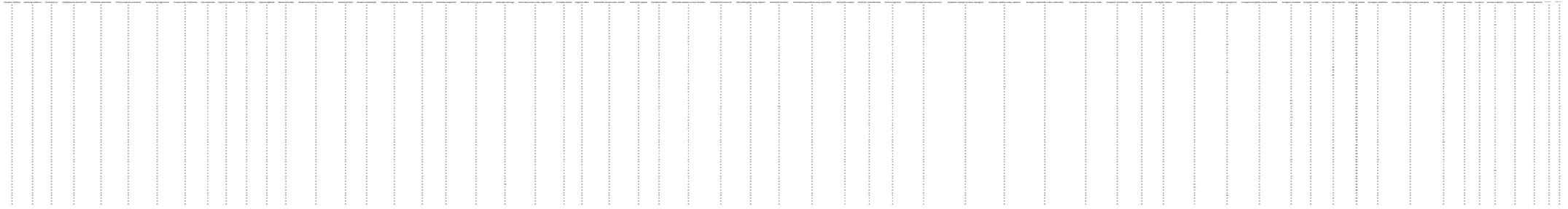
|                 |   |  |
|-----------------|---|--|
| Date custodian  | Carl Gosper   | <a href="mailto:carl.gosper@dec.wa.gov.au">carl.gosper@dec.wa.gov.au</a> |
|                 | All indices per 2500 m <sup>2</sup> area                        |  |
| Species_density | Number of species per plot (2500m <sup>2</sup> )                |  |
| Evenness        | Pielou's evenness calculated on cover data                      |  |
| Diversity       | Shannon diversity index ( $\log_e x$ ) calculated on cover data |  |

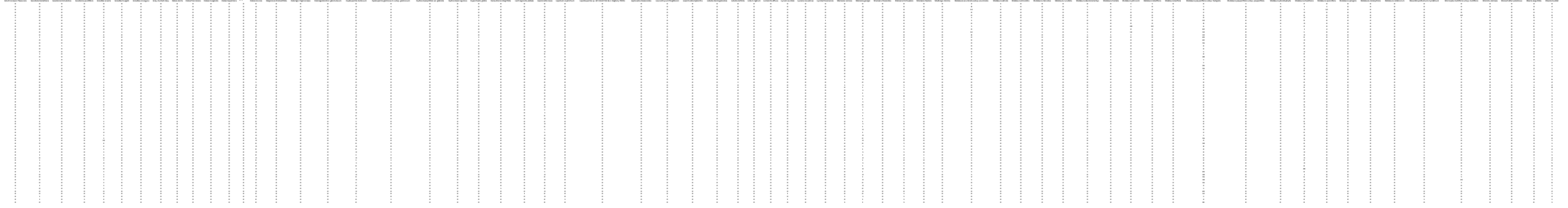
| Plot  | 1 m2 | 5m2 | 10m2 | 25m2 | 100m2 | 500m2 | 1000m2 | 2500m2 |
|-------|------|-----|------|------|-------|-------|--------|--------|
| GIM01 | 2    | 3   | 4    | 4    | 8     | 10    | 15     | 18     |
| GIM02 | 1    | 3   | 5    | 7    | 10    | 21    | 29     | 42     |
| GIM03 | 4    | 5   | 6    | 7    | 11    | 18    | 26     | 28     |
| GIM04 | 4    | 5   | 6    | 7    | 9     | 14    | 16     | 23     |
| GIM05 | 6    | 7   | 7    | 8    | 9     | 17    | 19     | 26     |
| GIM06 | 5    | 9   | 13   | 14   | 22    | 30    | 35     | 41     |
| GIM07 | 8    | 18  | 26   | 34   | 39    | 48    | 55     | 57     |
| GIM08 | 0    | 20  | 23   | 25   | 42    | 48    | 52     | 53     |
| GIM09 | 4    | 6   | 9    | 11   | 15    | 20    | 23     | 29     |
| GIM10 | 4    | 6   | 7    | 7    | 11    | 13    | 13     | 21     |
| GIM11 | 1    | 3   | 4    | 8    | 16    | 25    | 32     | 43     |
| GIM12 | 4    | 8   | 11   | 14   | 18    | 24    | 33     | 41     |
| GIM13 | 0    | 5   | 6    | 12   | 22    | 27    | 31     | 42     |
| GIM14 | 1    | 1   | 1    | 2    | 7     | 11    | 20     | 24     |
| GIM15 | 7    | 10  | 11   | 12   | 13    | 19    | 23     | 27     |
| GIM16 | 3    | 5   | 10   | 11   | 13    | 27    | 29     | 37     |
| GIM17 | 5    | 5   | 5    | 6    | 13    | 19    | 25     | 40     |
| GIM18 | 2    | 3   | 6    | 6    | 12    | 20    | 24     | 32     |
| GIM19 | 1    | 5   | 7    | 7    | 20    | 40    | 45     | 50     |
| GIM20 | 6    | 6   | 9    | 12   | 18    | 31    | 34     | 35     |
| GIM21 | 2    | 5   | 8    | 9    | 19    | 37    | 43     | 49     |
| GIM22 | 0    | 4   | 7    | 12   | 19    | 31    | 33     | 43     |
| GIM23 | 3    | 6   | 9    | 11   | 12    | 13    | 17     | 27     |
| GIM24 | 3    | 4   | 5    | 5    | 7     | 11    | 15     | 18     |
| GIM25 | 2    | 4   | 9    | 12   | 24    | 32    | 35     | 37     |
| GIM26 | 3    | 6   | 7    | 11   | 16    | 25    | 40     | 62     |
| GIM27 | 1    | 7   | 10   | 14   | 18    | 28    | 34     | 41     |
| GIM28 | 2    | 5   | 7    | 12   | 15    | 21    | 24     | 33     |
| GIM29 | 2    | 4   | 6    | 8    | 14    | 25    | 28     | 40     |
| GIM30 | 3    | 6   | 9    | 12   | 17    | 23    | 27     | 34     |
| GIM31 | 3    | 4   | 7    | 8    | 10    | 17    | 19     | 27     |
| GIM32 | 4    | 7   | 8    | 11   | 18    | 22    | 25     | 31     |
| GIM33 | 3    | 3   | 4    | 10   | 13    | 19    | 24     | 28     |
| GIM34 | 2    | 5   | 7    | 9    | 11    | 13    | 16     | 25     |
| GIM35 | 3    | 5   | 6    | 6    | 9     | 16    | 19     | 27     |
| GIM36 | 3    | 7   | 8    | 9    | 14    | 19    | 20     | 32     |
| GIM37 | 2    | 4   | 5    | 13   | 16    | 28    | 34     | 40     |
| GIM38 | 2    | 3   | 7    | 9    | 15    | 22    | 26     | 32     |
| GIM39 | 3    | 5   | 7    | 8    | 19    | 38    | 47     | 55     |
| GIM40 | 4    | 9   | 10   | 12   | 22    | 29    | 35     | 44     |
| GIM41 | 2    | 4   | 7    | 7    | 18    | 30    | 32     | 40     |
| GIM42 | 4    | 6   | 10   | 13   | 13    | 22    | 30     | 34     |
| GIM43 | 3    | 13  | 16   | 21   | 30    | 36    | 51     | 59     |
| GIM44 | 2    | 4   | 5    | 6    | 9     | 15    | 20     | 33     |
| GIM45 | 1    | 2   | 3    | 7    | 8     | 15    | 20     | 27     |
| GIM46 | 1    | 5   | 8    | 15   | 20    | 26    | 47     | 52     |
| GIM47 | 2    | 4   | 6    | 7    | 27    | 39    | 46     | 53     |
| GIM48 | 1    | 3   | 3    | 6    | 7     | 12    | 24     | 30     |
| GIM49 | 1    | 1   | 2    | 4    | 8     | 14    | 17     | 20     |

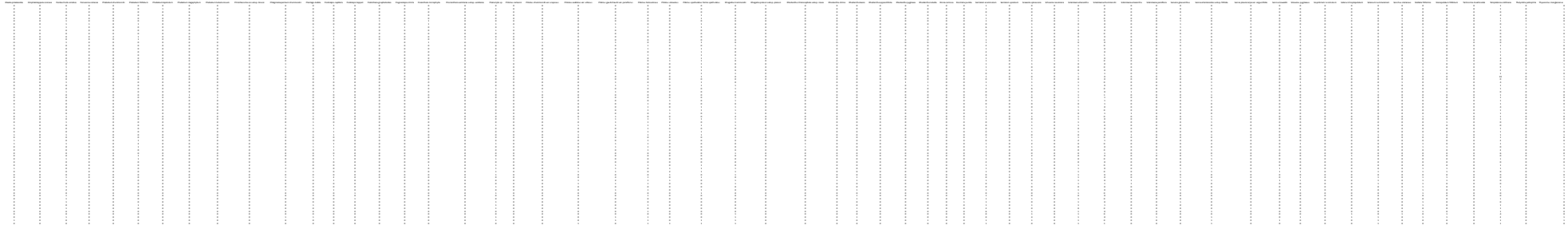
|       |   |    |    |    |    |    |    |    |
|-------|---|----|----|----|----|----|----|----|
| GIM50 | 0 | 4  | 6  | 7  | 11 | 22 | 27 | 36 |
| GIM51 | 0 | 1  | 3  | 8  | 10 | 21 | 32 | 41 |
| GIM52 | 2 | 4  | 4  | 7  | 11 | 16 | 30 | 33 |
| GIM53 | 3 | 5  | 8  | 9  | 14 | 28 | 30 | 46 |
| GIM54 | 2 | 5  | 11 | 17 | 23 | 38 | 42 | 55 |
| GIM55 | 4 | 9  | 9  | 12 | 18 | 29 | 32 | 49 |
| GIM56 | 1 | 5  | 6  | 10 | 20 | 28 | 29 | 31 |
| GIM57 | 8 | 13 | 16 | 20 | 29 | 39 | 44 | 56 |
| GIM58 | 4 | 19 | 21 | 30 | 46 | 52 | 57 | 71 |
| GIM59 | 0 | 3  | 7  | 10 | 14 | 16 | 22 | 38 |
| GIM60 | 1 | 5  | 7  | 10 | 18 | 24 | 26 | 28 |
| GIM61 | 8 | 13 | 17 | 27 | 40 | 55 | 59 | 62 |
| GIM62 | 1 | 1  | 2  | 3  | 6  | 15 | 19 | 25 |
| GIM63 | 0 | 3  | 6  | 12 | 25 | 37 | 43 | 49 |
| GIM64 | 3 | 3  | 6  | 7  | 15 | 21 | 26 | 47 |
| GIM65 | 7 | 8  | 8  | 10 | 16 | 27 | 33 | 36 |
| GIM66 | 3 | 5  | 8  | 13 | 19 | 23 | 28 | 41 |
| GIM67 | 8 | 14 | 19 | 20 | 25 | 29 | 33 | 39 |
| GIM68 | 1 | 3  | 4  | 12 | 16 | 17 | 22 | 24 |
| GIM69 | 3 | 4  | 4  | 5  | 6  | 16 | 17 | 35 |
| GIM70 | 1 | 1  | 1  | 6  | 15 | 45 | 55 | 61 |
| GIM71 | 2 | 3  | 10 | 15 | 23 | 41 | 44 | 52 |
| GIM72 | 1 | 1  | 5  | 6  | 9  | 17 | 21 | 31 |













## Notes to accompany floristic cover data

Date custodian

Carl Gosper [carl.gosper@dec.wa.gov.au](mailto:carl.gosper@dec.wa.gov.au)

### Methods for floristic sampling

Plots were sampled in spring 2010 or spring 2011, with each time since fire class sampled in each year.

For each plot we recorded the vascular plant taxa present and estimated their abundance.

To measure abundance we systematically placed a 12.5 mm diameter pole vertically at 50 points per plot (along two sides of the plot and the diagonal), each 3 m apart, and recorded the identity of all plants with live parts intercepting the pole.

Species that were present but not recorded at point intercepts were allocated a nominal proportional abundance of 1%.

Taxonomy follows the Western Australian Herbarium (1998-2012) as at Jan 2012.

| Plot_Number | Ammonium | Nitrate | P  | K   | Sulphur | Organic_C | Conductivity | pH (CaCl2) |
|-------------|----------|---------|----|-----|---------|-----------|--------------|------------|
| GIM01       | 1        | 1       | 4  | 223 | 5.29    | 1.27      | 0.122        | 6.4        |
| GIM02       | 0.5      | 1       | 1  | 187 | 2.16    | 0.85      | 0.075        | 6.4        |
| GIM03       | 1        | 0.5     | 5  | 130 | 10.6    | 0.99      | 0.21         | 6.4        |
| GIM04       | 1        | 3       | 2  | 373 | 4.21    | 1.83      | 0.157        | 7.8        |
| GIM05       | 1        | 1       | 1  | 225 | 1.98    | 0.91      | 0.146        | 7.8        |
| GIM06       | 1        | 2       | 1  | 211 | 2.73    | 0.97      | 0.075        | 7.2        |
| GIM07       | 1        | 4       | 2  | 221 | 3.77    | 0.77      | 0.099        | 6.5        |
| GIM08       | 1        | 3       | 1  | 404 | 2.05    | 0.78      | 0.12         | 7.6        |
| GIM09       | 1        | 1       | 1  | 176 | 3.88    | 1.13      | 0.127        | 7.1        |
| GIM10       | 1        | 1       | 2  | 185 | 12.5    | 0.97      | 0.259        | 6.5        |
| GIM11       | 1        | 1       | 2  | 197 | 1.93    | 0.94      | 0.031        | 5.7        |
| GIM12       | 1        | 4       | 2  | 274 | 2.08    | 1.03      | 0.1          | 6.9        |
| GIM13       | 0.5      | 1       | 2  | 147 | 1.07    | 0.44      | 0.02         | 6.6        |
| GIM14       | 1        | 4       | 4  | 475 | 2.46    | 1.28      | 0.071        | 6.7        |
| GIM15       | 1        | 5       | 4  | 466 | 5.49    | 1.9       | 0.195        | 7.7        |
| GIM16       | 1        | 3       | 3  | 448 | 3.09    | 1.2       | 0.186        | 7.6        |
| GIM17       | 1        | 7       | 6  | 356 | 4.24    | 1.31      | 0.283        | 7.7        |
| GIM18       | 1        | 2       | 2  | 371 | 2.04    | 0.89      | 0.065        | 6.3        |
| GIM19       | 1        | 0.5     | 2  | 243 | 1.6     | 0.68      | 0.145        | 7.7        |
| GIM20       | 1        | 2       | 3  | 186 | 3.13    | 1.15      | 0.081        | 5.6        |
| GIM21       | 1        | 1       | 1  | 86  | 0.92    | 0.42      | 0.018        | 6.3        |
| GIM22       | 2        | 2       | 2  | 40  | 1.53    | 0.72      | 0.044        | 6.3        |
| GIM23       | 1        | 1       | 1  | 88  | 1.96    | 0.67      | 0.028        | 6.3        |
| GIM24       | 2        | 2       | 4  | 264 | 6.43    | 1.27      | 0.183        | 6.2        |
| GIM25       | 1        | 2       | 2  | 163 | 2.04    | 0.71      | 0.075        | 5.9        |
| GIM26       | 2        | 4       | 4  | 193 | 9.51    | 1.82      | 0.098        | 6.1        |
| GIM27       | 1        | 2       | 1  | 237 | 1.73    | 0.79      | 0.156        | 7.1        |
| GIM28       | 1        | 1       | 3  | 198 | 3.22    | 0.48      | 0.065        | 7.2        |
| GIM29       | 2        | 3       | 5  | 180 | 2.37    | 0.47      | 0.019        | 5.1        |
| GIM30       | 1        | 6       | 8  | 176 | 3.94    | 0.98      | 0.1          | 5.8        |
| GIM31       | 2        | 9       | 5  | 172 | 20.7    | 1.93      | 0.253        | 5.8        |
| GIM32       | 2        | 8       | 9  | 400 | 3.6     | 1.46      | 0.115        | 6.5        |
| GIM33       | 1        | 2       | 5  | 223 | 1.39    | 0.85      | 0.046        | 6.1        |
| GIM34       | 1        | 1       | 4  | 421 | 1.4     | 0.77      | 0.161        | 7.2        |
| GIM35       | 1        | 7       | 3  | 169 | 2.64    | 1.05      | 0.086        | 6.5        |
| GIM36       | 1        | 9       | 4  | 248 | 3.04    | 1.19      | 0.069        | 5.9        |
| GIM37       | 1        | 1       | 6  | 394 | 1.09    | 0.87      | 0.112        | 7.4        |
| GIM38       | 1        | 2       | 16 | 352 | 1.91    | 0.91      | 0.123        | 7.6        |
| GIM39       | 1        | 2       | 5  | 245 | 2.87    | 0.83      | 0.074        | 7          |
| GIM40       | 1        | 1       | 4  | 221 | 1.32    | 0.55      | 0.018        | 5.8        |
| GIM41       | 1        | 1       | 3  | 132 | 1.37    | 0.6       | 0.028        | 6.1        |
| GIM42       | 1        | 2       | 3  | 143 | 1.37    | 0.77      | 0.049        | 5.9        |
| GIM43       | 1        | 1       | 14 | 148 | 0.96    | 0.59      | 0.02         | 5.8        |
| GIM44       | 1        | 6       | 6  | 252 | 9.93    | 1.12      | 0.296        | 6.2        |
| GIM45       | 2        | 23      | 5  | 246 | 9.04    | 1.78      | 0.247        | 6.2        |
| GIM46       | 1        | 1       | 2  | 409 | 1.31    | 0.71      | 0.105        | 7.1        |
| GIM47       | 1        | 2       | 3  | 197 | 1.56    | 0.47      | 0.036        | 6          |
| GIM48       | 1        | 1       | 4  | 229 | 2.41    | 1.18      | 0.101        | 6.8        |
| GIM49       | 1        | 3       | 3  | 311 | 5.48    | 0.99      | 0.205        | 6.6        |

GIM50  
GIM51  
GIM52

|   |   |   |     |      |      |       |     |
|---|---|---|-----|------|------|-------|-----|
| 1 | 1 | 2 | 216 | 3.15 | 0.62 | 0.075 | 5.2 |
| 1 | 3 | 3 | 204 | 10.8 | 0.84 | 0.233 | 6.1 |
| 1 | 3 | 8 | 255 | 6.33 | 1.43 | 0.221 | 6.2 |

## Notes to accompany soils data spreadsheet

Date custodian

Carl Gosper

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### Methods for soil sampling

We analysed a single bulked sample of the top 10 cm of soil from aggregation of multiple 2 cm diameter sub-samples collected from throughout each of 52 50 x 50 m plots sampled in spring 2010.

Samples were stored at ~4°C until delivery to the CSBP Futurefarm analytical laboratories (Bibra Lake, WA), where they were thoroughly mixed, air dried at 40 °C, and ground to pass through a 2 mm sieve.

Analyses were undertaken on each bulked sample as follows (where given, method numbers apply to Rayment and Higginson 1992)

available phosphorus (Colwell method, bicarbonate-extractable phosphorus - manual colour, 9B1)

potassium (Colwell method, bicarbonate-extractable potassium, 18A1)

ammonium and nitrate (measured simultaneously using Lachat Flow Injection Analyser, soil:solution ratio 1:5, 1M KCl, indophenol blue, Searle 1984, and with copperized-cadmium column reduction)

organic carbon (Walkley and Black method, 6A1)

extractable sulphur (40°C for 3 hours, 0.25M KCl, measured by ICP; Blair et al. 1991)

pH (1:5 soil/0.01M CaCl<sub>2</sub>, 4B2)

conductivity (1:5 soil:water extract, 3A1)

Blair GJ, Chinoim N, Lefroy RB, Anderson GC, Crocker GJ (1991) A soil sulfur test for pasture and crops. *Aust J Soil Res* 29:619–626  
Rayment GE, Higginson FR (1992) *Australian Laboratory Handbook of Soil and Water Chemical Methods*. Inkata Press, Melbourne  
Searle PL (1984) The berthelot or indophenol reaction and its use in the analytical chemistry of nitrogen. A review. *Analyst* 109:549-568





Notes to accompany plot details

Date custodian

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Steel dropper in NW corner of plot. Plot 50 x 50 m, sides aligned N-S & E-W (except see notes)

All plots

|                          |   |
|--------------------------|---|
| Plot number              |   |
| Datum                    |   |
| Zone                     |   |
| Easting                  | NB - in text format to preserve 0   |
| Northing                 |   |
| Latitude                 |   |
| Longitude                |   |
| Location accuracy        |   |
| Elevation                | metres ASL  |
| Aspect                   |   |
| Topo position            |   |
| Location                 |   |
| Tenure                   | UCL = unallocated crown land; NR = Nature Reserve   |
| Date established         |   |
| Vegetation               | Lists dominant canopy species   |
| Surface soil description |   |
| Soil_sample              | Sample number   |
| Photos                   | Y = Yes for plot photo(s)   |
| Species-area             | Y = Yes for species-area curve data collected   |
| Flora_richness           | Y = Yes for species richness determined per 2500 m <sup>2</sup> plot  |
| Flora_cover              | Y = Yes for floristic cover   |
| Veg_structure            | Y = Yes for vegetation structure measured   |
| Fuel                     | Y = Yes for fuel assessment conducted   |
| LS Fire year             | Year of fire from Landsat image analysis (if known)   |
| LS Yrs since fire        | Years since fire from Landsat image analysis  |
| Model 2 fire date        | Year of fire (= number of growing seasons post-fire, not necessarily calendar year) from estimates from growth ring counts and growth ring-size relationships. Using Model 2 of Gosper et al. (2013). |
| Model 2 yrs since fire   | Years since fire (growth seasons) from estimates from growth ring counts and growth ring-size relationships. Using Model 2 of Gosper et al. (2013).   |

|                        |   |
|------------------------|---|
| Model 5 fire date      | Year of fire (= number of growing seasons post-fire, not necessarily calendar year) from estimates from growth ring counts and growth ring-size relationships. Using Model 5 of Gosper et al. (2013). |
| Model 5 yrs since fire | Years since fire (growth seasons) from estimates from growth ring counts and growth ring-size relationships. Using Model 5 of Gosper et al. (2013).   |
| Dating method          | Method used for determining 'Model 2 (or 5) yrs since fire': L = Landsat, R = growth ring count, E = estimate from growth ring-size relationship  |
| Notes                  |   |

See: Gosper, C.R., Prober, S.M., Yates, C.J. and Wiehl, G. (2013) Estimating the time since fire of long-unburnt *Eucalyptus salubris* stands in the Great Western Woodlands. *Australian Journal of Botany* 61, 11-21.