MONJEBUP NORTH Ecological Restoration Planning Project








THRESHØLD ENVIRONMENTAL

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MONJEBUP NORTH
Ecological Restoration Plan

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EXECUTIVE SUMMARY:

This document is one part of a 4 part Monjebup Ecological Restoration Plan:

- **ECOLOGICAL RESTORATION PLAN (Part I)**
- **SPECIFICATIONS FOR ESTABLISHMENT (Part II)**
- **PROJECT TIMELINES, COSTS, & RESEARCH OPPORTUNITIES (Part III)**
- **THE VEGETATION OF MONJEBUP NORTH**

These documents aim to provide restoration practitioners with information required to execute a 5 star ecological restoration project.

INTRODUCTION:

Ecological restoration is defined by the Society for Ecological Restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER 2004). At the core of the definition is the concept of the ecosystem, which is defined as a biological environment consisting of all the organisms living within a particular area, including both living (biotic) and nonliving (abiotic) physical components of that space.

Ecological systems are known to be highly dynamic entities which can vary over time and across space (Palmer et. al., 2006). Ecosystems are not merely the sum of their parts, but rather something greater that is achieved when the collective interactions of the entire system produce a self replicating, and self sustaining entity. Such systems are complex and contain both positive and negative feedback loops which in turn regulate the balance of production, consumption, and decay.

While the multitude of interactions that contribute to these complex systems are beyond easy comprehension, a combined approach which relies on a set of manageable assumptions and applied restoration principals, can be used to set a rigorous trajectory toward restoration. Key variables to achieving these ends are 1) productivity, 2) diversity, and 3) composition.

The great unknown amongst the science of restoration ecology is 'how much is enough'? And 'enough for what', as there are many different organisms to consider. Aside from changes in presence/absence records for the occupancy of a specific organism following restoration, no specific metric has been developed to quantify the point at which a recreated system has shifted to a functional state similar to the pre-cleared or degraded system. Time, and the ability of a system to respond to disturbances (through recruitment and succession) is one such framework, but little work has been done on this topic to date. While changes to presence/absence data for fauna at a specific restoration site are useful, such records can strongly reflect external variables that do not reflect on the quality of the site (Gaston and Blackburn 2000). For example, adjacency to locations in the landscape that serve as sources of progeny from existing fauna populations will result in very different conditions from sites that are located in less favourable locations. This highlights that the efficacy of restoration is not easily compared, and sites vary considerably from one location to another.

The question of how much energy we need to input into an area of land in order for it to cross a threshold from a suite of re-established plants to a fully functioning, self replicating, resilient ecosystem which supports new populations of local fauna, is not clear. Considering the dispersal limited nature of the local flora in the south west of WA (Hopper and Gioia, 2004), caution should be applied to any assumptions that simple mixes of easily established plant species will achieve these ends. This includes assumptions applied over medium to long time frames. However, this plan includes a specific directive to focus on the restoration of habitat for local fauna. In this way, the restoration should be underpinned by the species compositions of native plant communities, yet highlight the specific elements within those assemblages that support local fauna populations.

Speaking metaphorically, restoration can be compared to building a house. First one must ensure a solid foundation is poured. Next, the walls and roof must be constructed from appropriate materials. In this instance, the house can be compared to the reconstructed plant community. In order to ensure that a strong foundation was achieved, a vegetation survey was undertaken. The purposed of this survey was to define a suite of analogue plant communities which could guide the development of species mixes to use for restoration of the cleared lands. Soil sampling was also included to assist in providing continuity between cleared and un-cleared areas, and allow for the reconstruction of plant communities consistent with the surrounding mosaic. The approach draws from current ecological theory on the three accepted models of plant community assembly (Temperton & Hobbs, 2004).

- **Deterministic** - inevitable consequence of physical & biotic factors
- **Stochastic** - community composition & structure essentially a random process
- **Alternative Stable States** - intermediate between 1&2; numerous stable states

While there is a clearly defined natural mosaic expressed by the vegetation in the Fitz-Stirling landscape which is deterministic in its presence, there are also a number of cases in which the ‘deterministic’ variables do not directly align with what is observed on the ground. The combination of the extreme heterogeneity of soils at the patch scale, and the dispersal limited characteristics of the local vegetation, result in a intricate mosaic where ecotones between different deterministic systems are also abundant. The result is a complex and ever changing mosaic of deterministic vegetation associations interspersed with vegetation which reflects a number of alternative stable states. There are numerous examples at Monjebup North which exemplify this process, including the drainage systems (VEG Survey WayPoint002; WP035 and WP038) and the riparian Yate system (WP001). Other examples of these ecotone vegetation associations were VEG Survey WP024, which had a mix of plant species often found in association with either ‘light’ or ‘heavy’ soil types.

The point of emphasis here is that the planning required for the ecological restoration of a plant community mosaic itself, is a challenging task that requires significant time and energy to get right. In simple terms we can refer to this as the front end of the planning. Getting back to our metaphor, a solid house is required if one seeks to sustain inhabitants over time.

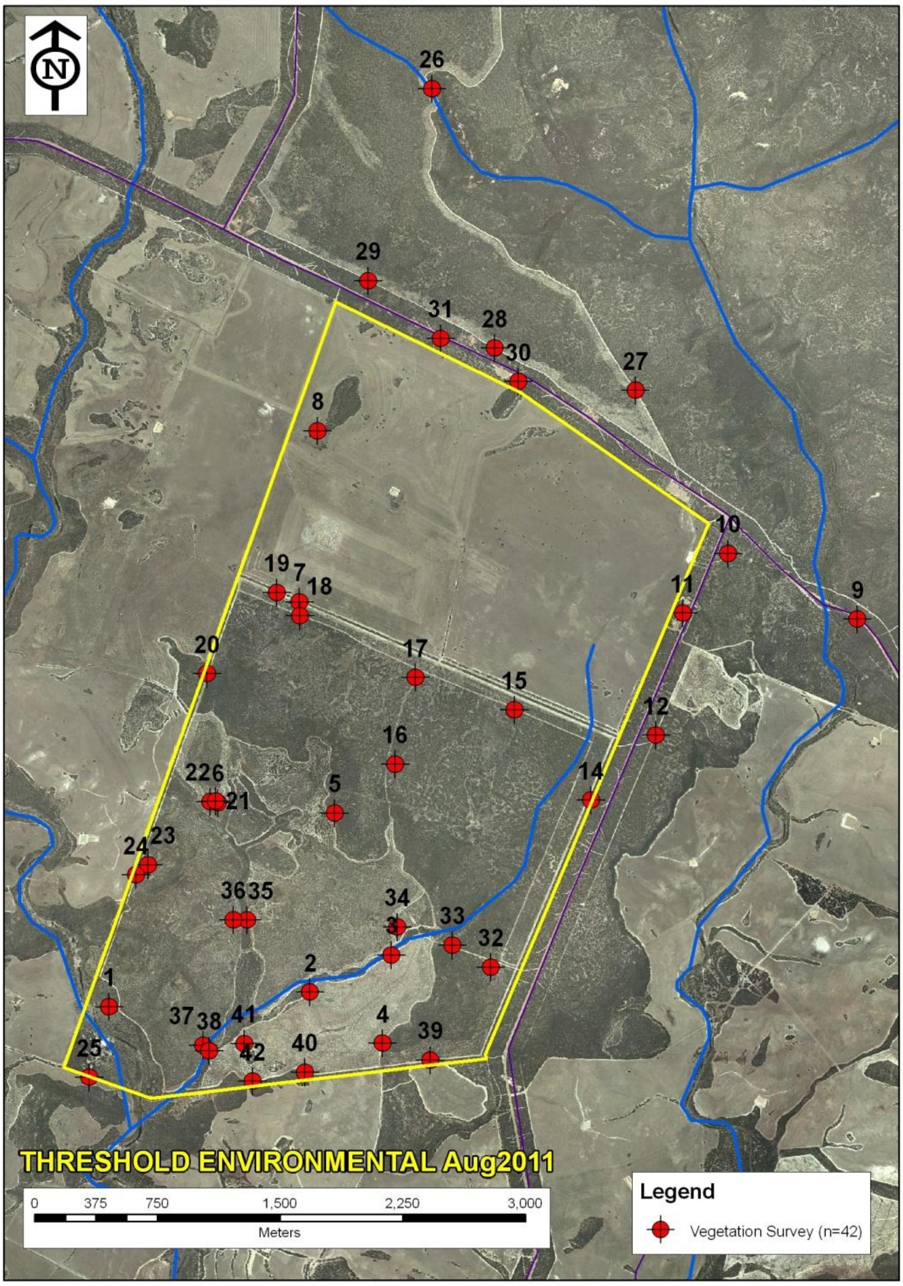
Wildlife restoration is also a very complex field of practice where the ultimate goal is to ensure the survival and protection of individual animals (Morrison 2002). To achieve this goal, the restoration must seek to recreate suitable habitat. Although habitat is ultimately a species-specific concept (Morrison 2002), broad ecological functions and processes are the starting point for achieving these ends. Using birds as an example, provision of restoration habitat qualities (i.e. flowering plants over all seasons; leaf litter and debris; rock piles and soil heaps; loose burrow-able soil; fallen logs; seed and fruit bearing plants) specific to the functional groups and their resource requirements outlined by Sanders (2011) is an excellent example.

Restoration ecology is a newly developing field in which much opportunity exists to implement innovative approaches to restoring degraded ecosystems. At the center of this field is the goal of overcoming thresholds in ecosystem functionality, through the reestablishment of self-replicating ecosystems that provide suitable habitat conditions for local fauna.

METHODS:

VEGETATION SURVEY
A vegetation survey was initiated to survey the remnant vegetation on, and around Monjebup North. Nathan McQuoid was sub-contracted to provide expert botanical identification. Survey sites were selected to capture the full distribution and spatial extent of representative vegetation associations (plant communities). For each survey site, plants visible within an approximate area of 10 x 10 meters of the established location were identified and recorded. GPS and photo information were also recorded. A field herbarium was built and later used to identify unknown species from specimens on record at the Albany Regional Herbarium. Data from the field was entered into excel spreadsheets where it was then analyses using a combination of two-way analyses (after Craig et al., 2007; Sandiford and Barrett, 2010) and cross referenced geospatial data and on-ground observations (after Jonson, 2010). This data was checked, and rechecked, a number of times to produce classifications as accurate as possible.

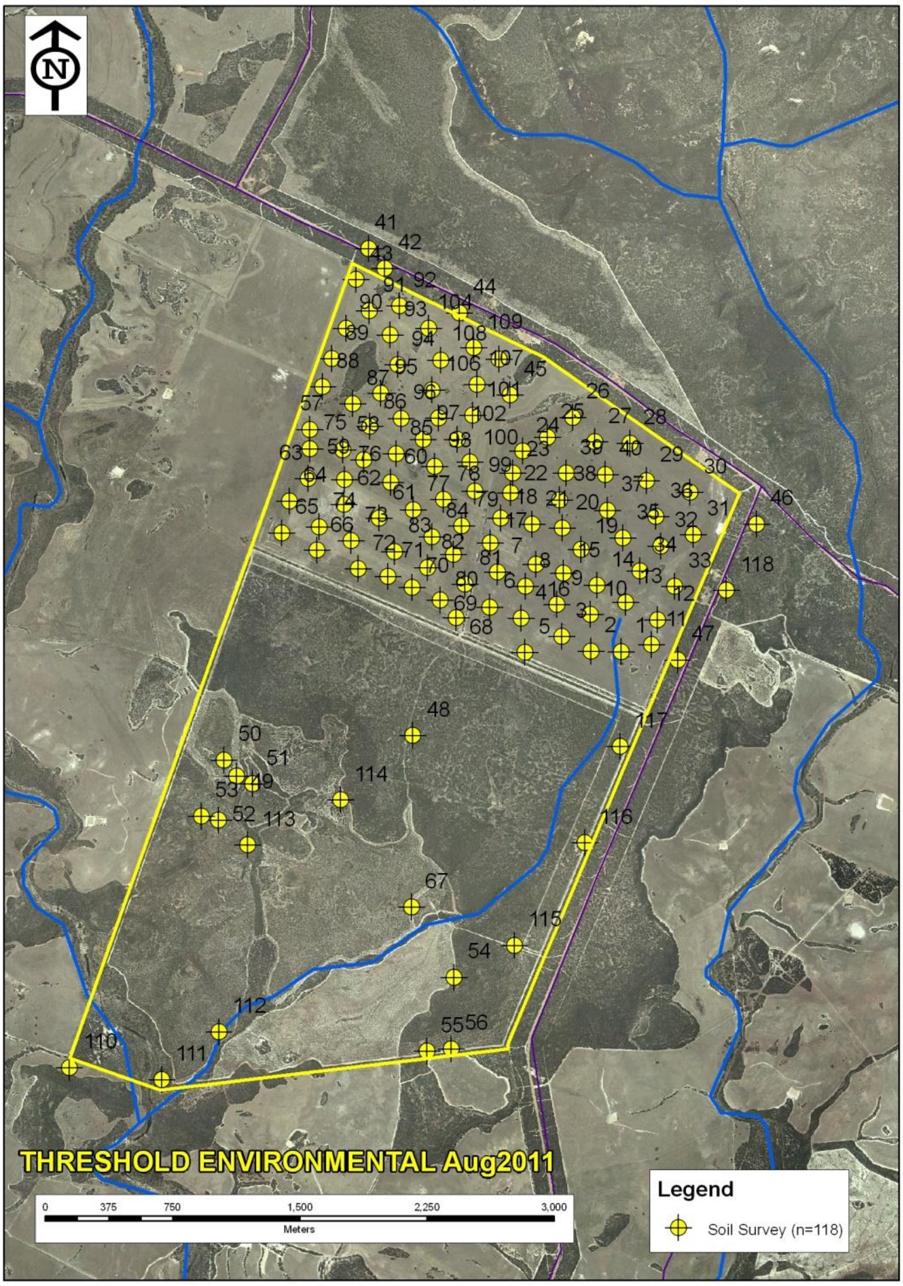
Figure 1. Distribution of Vegetation Survey Sites



SOIL SURVEY

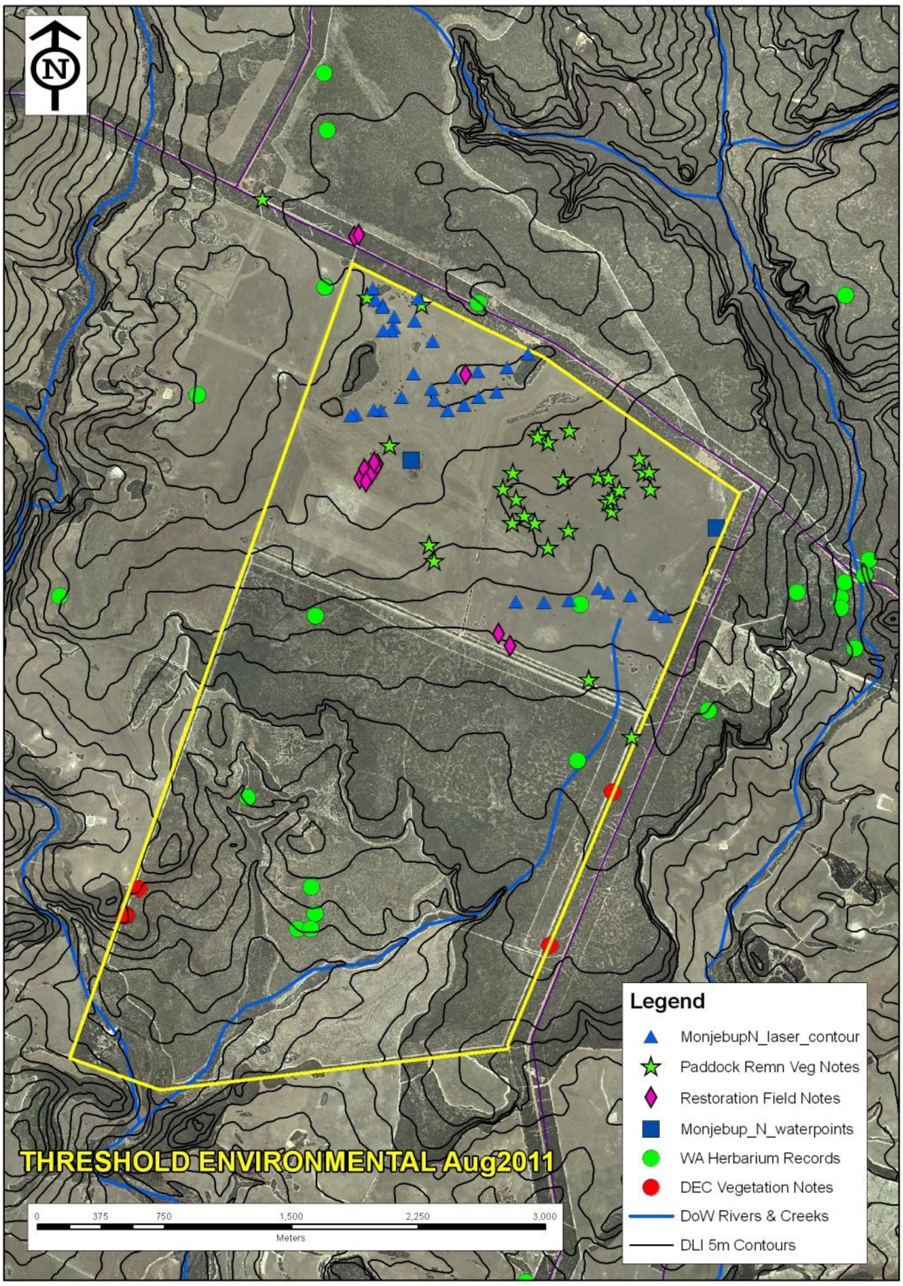
A soil survey was also initiated to survey the type, profile, and distribution of soils at Monjebup North. The majority of this sampling occurred on the cleared land, as this was the primary focus of the project, however a number of soil samples were also taken in remnant bushland areas to calibrate relationships to remnant vegetation types. A hand powered mechanical auger was used at each soil sampling location. Soil was removed in a series of steps to allow for information to be recorded on the depth of each successive profile. A tape measure was used to record the approximate zone of each soil change. An effort was made to auger to a minimum depth of 500mm, or until an impermeable layer was reached. Augured soil materials were laid out in successive order to provide a photographic record of the profile. A GPS recording was taken for each soil pit.

Figure 2. Distribution of Soil Auger Survey Sites.



ADDITIONAL SPATIAL DATA
In addition to the vegetation and soil surveys, a number of other observations were included in the development of the proposed restoration map and recommendations. Species identification and GPS location of paddock trees remaining within the cleared land were recorded. A drive around the site with Geoff Plain was also undertaken to record his knowledge on the history of the site. A number of contour lines were also shot with a laser level to provide guidance on vegetation boundaries between certain systems, and to provide benchmark contour lines to validate or dispute available GIS contour shapefiles.

Figure 3. Additional Spatial Input Data used for interpretation



Field data was interpreted and analysed using GIS software. The analysis included the use of additional geospatial data to inform classifications. A number of follow-up field trips were also undertaken to check, validate, and refine the initial outputs from analyses.

The full analysis of the soil and vegetation data was achieved through an iterative process, where results were proposed, tested, and then re-evaluated if possible. Continual reference to the input data underpinned each decision leading to the final results.

FAUNA INPUT DATA

In addition to the soil survey, vegetation survey and additional geospatial data inputs, information on the presence of fauna (146 species) from sites across the Fitz-Stirling pathway (Monjebup South, Monjebup North, Chingarup, Nowanup, Chereninup, and Peniup) were provided by Bush Heritage Ecologist Angela Sanders (Appendix A). In addition to this raw data, an analysis of the fauna requirements to guide the restoration of habitat at Monjebup North was also provided (Sanders 2010). This report detailed the stratification of bird functional groups, foraging strategies, plant genera most visited, and nesting materials used. It also provided analyses of shelter elements, food sources, and foraging strata for both mammals and reptiles (Sanders 2010).

Result tables from those analyses, from Sanders (2010) are summarised below:

Figure 4. Percent of bird functional groups, foraging strata, plant genera visited, and nesting materials expected at Monjebup North (Sanders 2010).

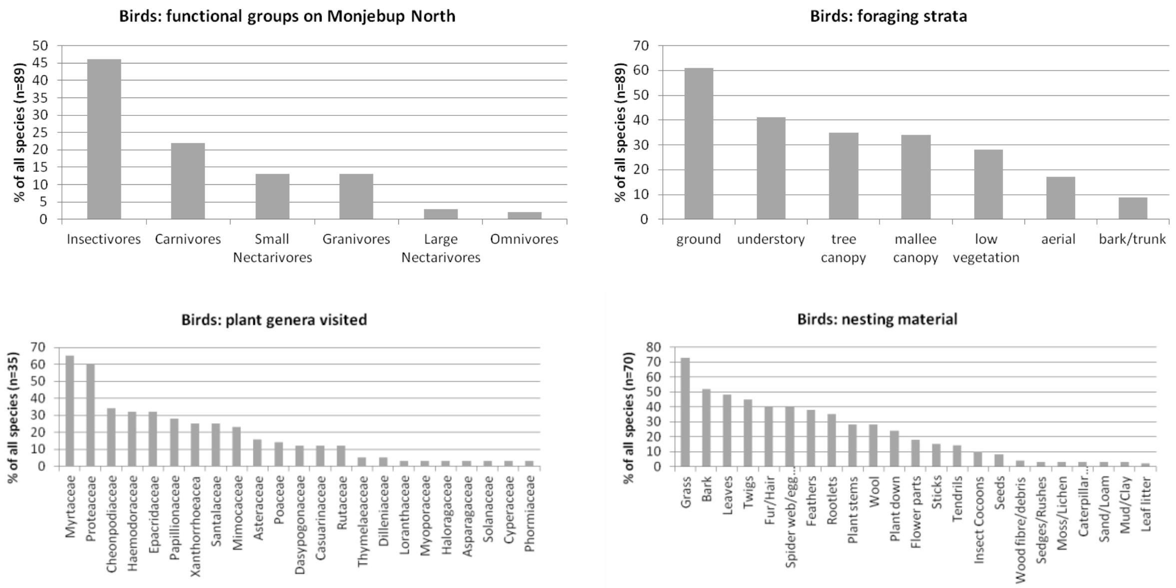
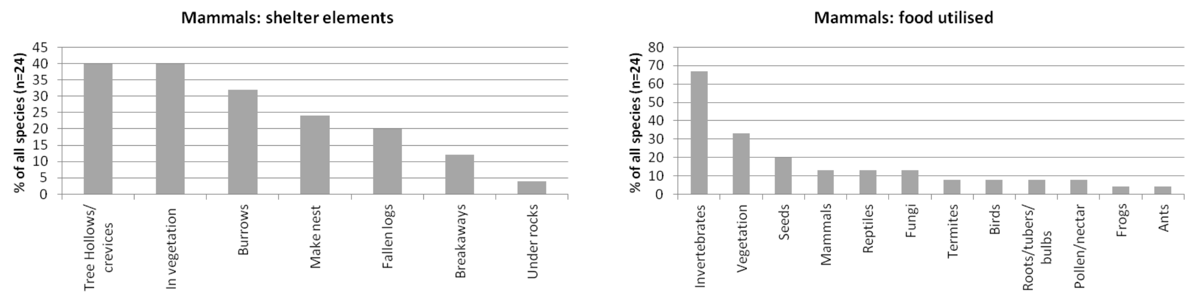


Figure 5. Percent of mammal shelter elements, food utilised, and feeding strata expected at Monjebup North (Sanders 2010).



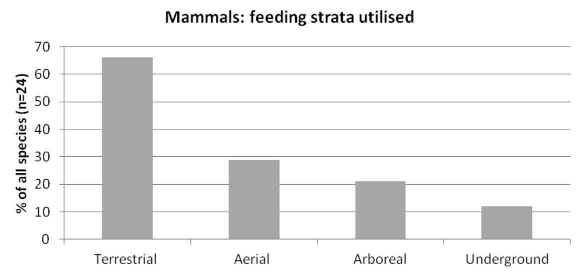
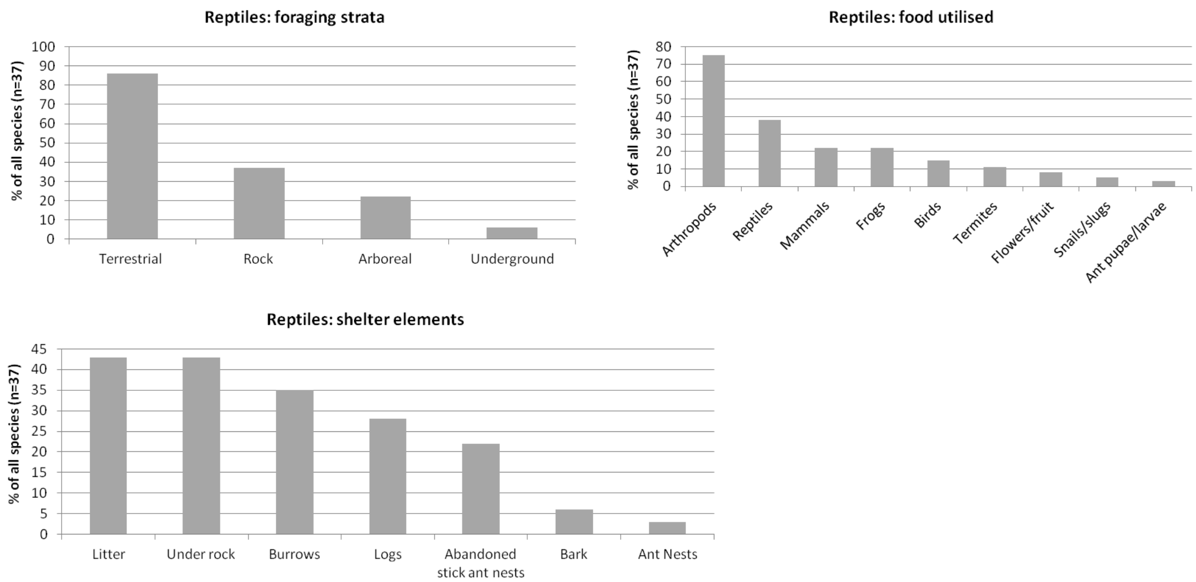


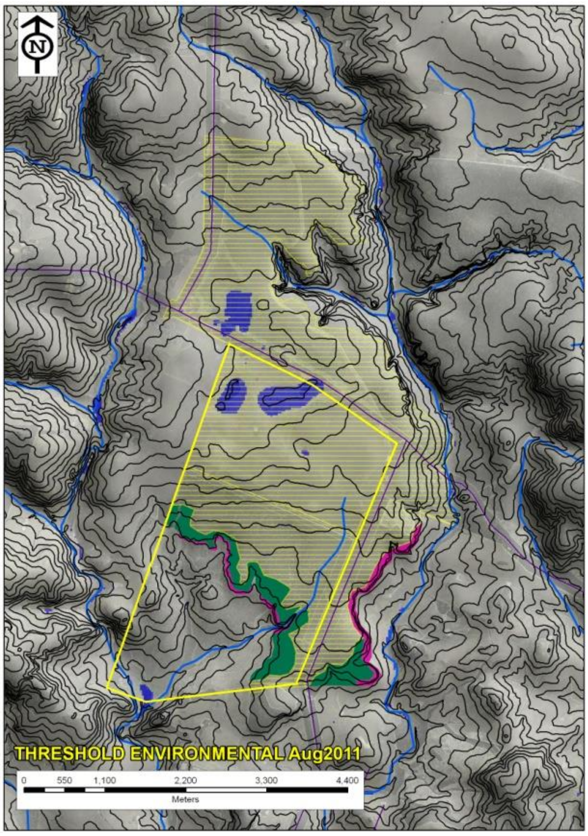
Figure 6. Percent of reptile foraging strata, food utilised, and shelter elements expected at Monjebup North (Sanders 2010).



RESULTS:

Vegetation of Monjebup N

Given the size of the Monjebup North property, and the scope of services defined in the brief, there was not sufficient time to map every area of the remnant vegetation in great detail. One area which presented significant difficulty for such fine scale mapping of vegetation association boundaries were the large topographical 'flats'. The extent of these 'flats' are identified by the yellow hashed areas of Monjebup North and the Corackerup N.R. in the image to the right. While this broad land unit seems relatively uniform and consistent across its extent, subtle differences were identified through analysis of the soil and vegetation data collected on- ground. A defining element of the vegetation of this landform is the presence of relatively wide spaced ***Banksia media*** trees with a dense low Melaleuca heath-like understory. As a result of the analysis of data collected on-ground, it was determined that there were at least two main systems which warranted separate classification. These were the **MN1 – *Banksia media, Eucalyptus falcata*** **and *Dryandra circioides***, and the **MN2 – *Banksia media, Eucalyptus pleurocarpa*** **and *Eucalyptus pluricaulis*** Mallee Scrub systems. It is proposed that the subtle difference between these two systems is the result of the underlying soil profile, where MN1 is primarily a sandy-ironstone-gravel influenced system, and MN2 is primarily a shallow-spongelitic-duplex influenced system.



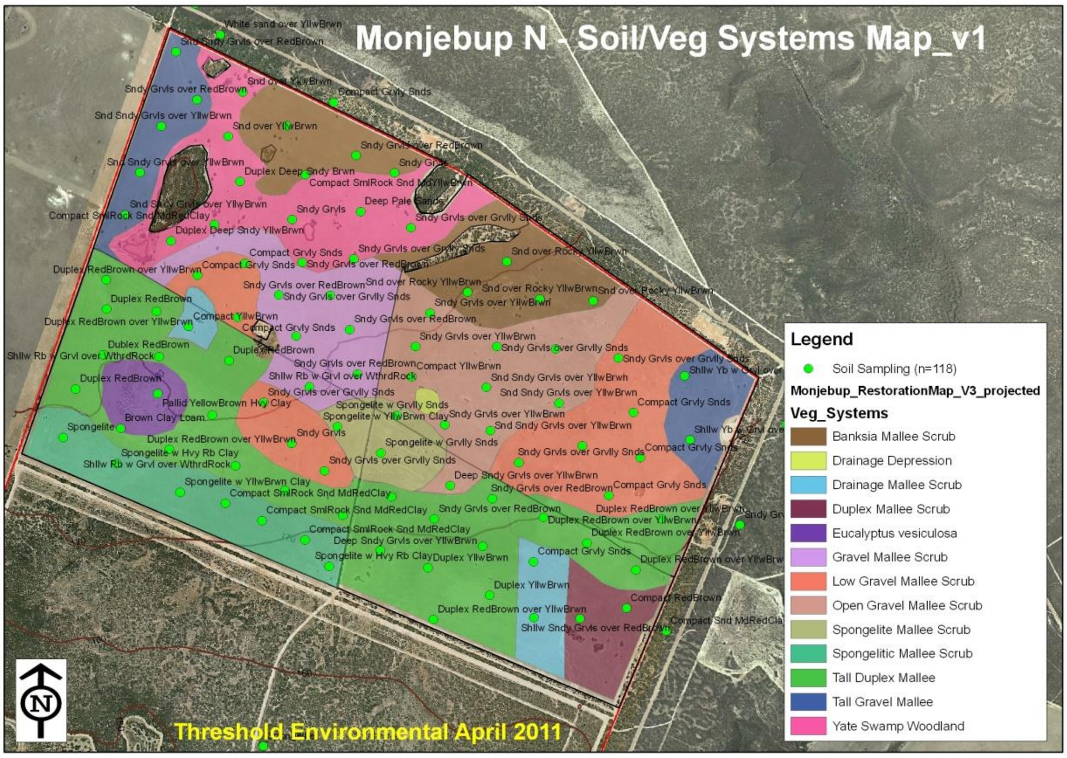
Several other landscape features are observed in the context of the Banksia 'flats'. The presence of large topographical depressions (shown as deep blue pools in the image above) highlight the lack of relief within this landscape unit. It should also be noted that a number of small cave-like drainage features have been found across this area, including several on the cleared areas of Monjebup North. The origins and hydrological implications of these features is well beyond the scope of this analysis, but warrants further investigation. Another feature which is also associated with the Banksia 'flats' is the spongelitic ridge (dark green in image above) and breakway (bright pink in image above) which define the border between the nutrient poor upland flats and the lower richer soils of the site. This division is of interest in understanding the site and its ecological and hydrological interaction within the local landscape.

Soils of Monjebup N

The results of the soil sampling effort help us to interpret some of the biotic variables that occur below ground. Given the scale of the property, and the scope of the project for a restoration plan of the cleared paddock areas to the north, the full extent of soil types and distributions across the entire site was not possible. In the interest of providing a very solid soil based underpinning to guide restoration of the cleared lands, the majority of soil pits were sampled in those areas.

Using the soil description data recorded in-field, in combination with photographs (see Appendix A) and GIS mapping, a preliminary soil/vegetation systems map was developed. Abbreviated soil classifications were used to bulk similar sub-units in order to begin to define soil boundaries. Initial maps developed through this process were checked, and checked again, until an acceptable level of precision was achieved. An example of one of these preliminary maps is provided in Fig. 5.

Figure 5. Preliminary Soil/Veg Systems Map for cleared areas



As previously indicated, the restoration design followed an iterative process where information gathered from both the soil sampling and vegetation survey were used interchangeably to map a proposed restoration layout for the cleared land. Soil data from each augered pit provided information on the number, extent and depth of each soil profile. An example of this information is provided below for pit 42.

Pit 42 (1)

Pit 42 (2)

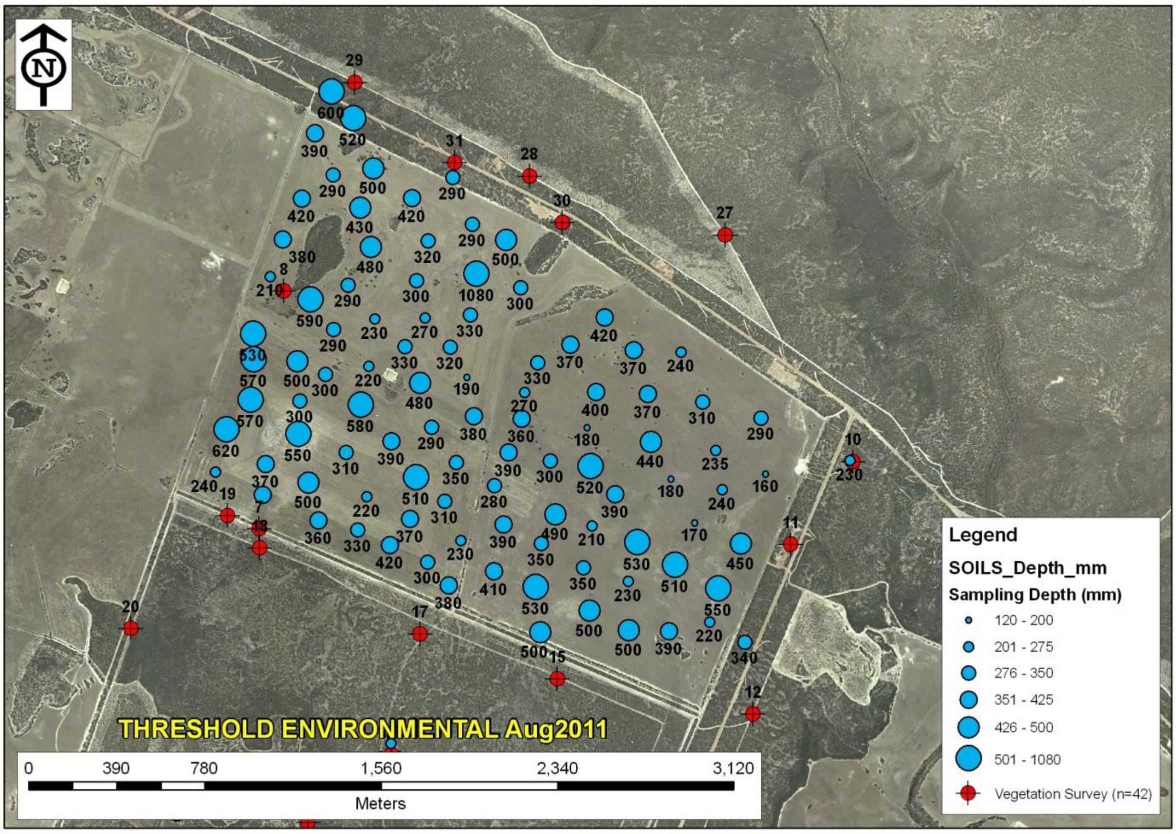
Pit 42 (3)

Pit 42 (4)

PitNo	A Horizon	Horizon2	Horizon3	Horizon4	Photos	SWHC	Notes
42	0-220mm gritty pale snd	220-270mm gritty pale snd w/some grvl	270-340mm pink gritty snd w/ some mottled clay	340-520mm yellow brown medium gritty clay	16-19	Medium	E.falcata and B.media Scrub; Open with thickets

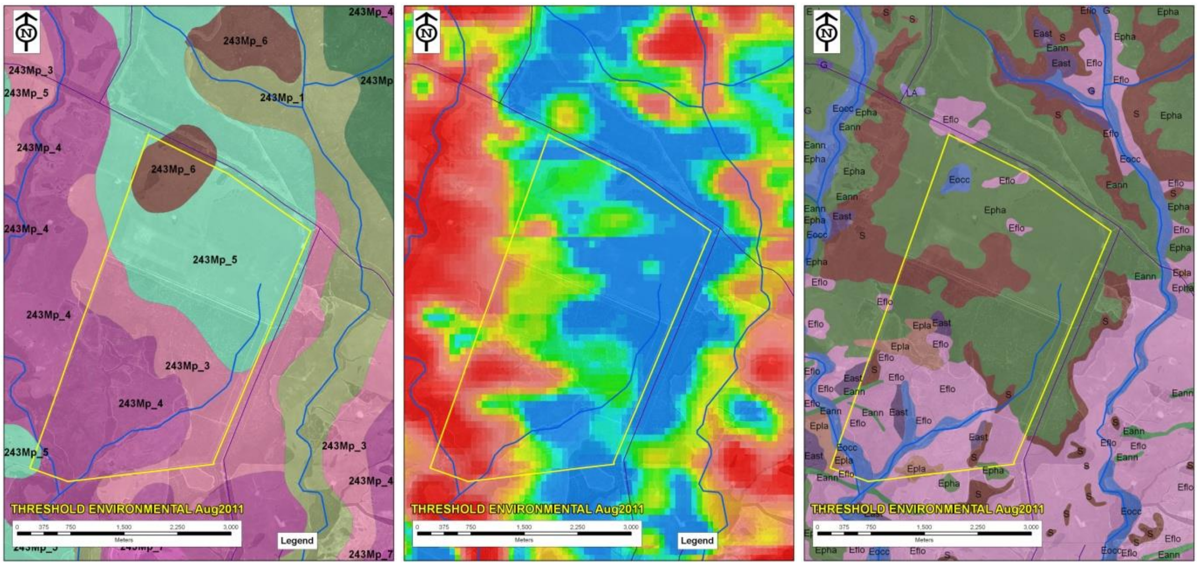
The soil data was also used to inform the ecological restoration plan indirectly, through different mapping techniques. For example, using the maximum soil depth able to be sampled using hand augers, an indication of the water holding capacity and the estimated vegetative productivity for the cleared areas could be made.

Figure 6. Visual depiction of soil depth able to be sampled using a hand auger.



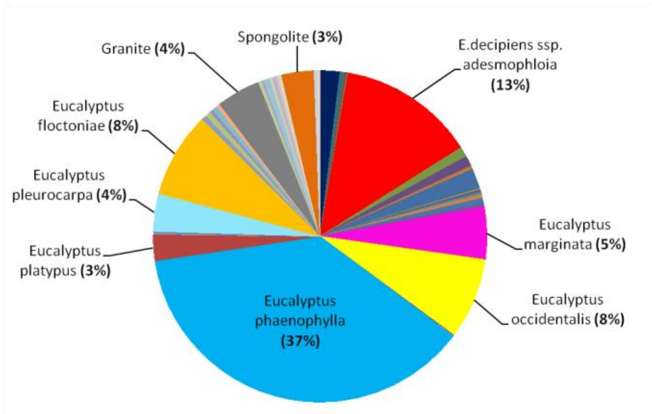
As previously stated, ecological restoration planning is an iterative process that produces designs which draw from soil, vegetation and other geospatial data. Some examples of additional geospatial data used to execute this process is shown below (Fig. 7).

Figure 7. Three different map input layers including the AgWA Soil Sub-systems (left), an interpolated Gama Radiometric layer for potassium (center), and Newbey's Vegetation map (left).



While the AgWA sub-system soil mapping is helpful at the landscape level, the resolution at the patch/property scale is not conducive to detailed ecological restoration planning. The 243Mp_5 soil type that dominates the cleared portion of Monjebup North has been defined by to be mostly colluvium (weathering in situ) on Tertiary (65 million to 2.6 million years ago) sediments, consisting of lateritic and granitic parent materials. Key information to gather from that description are that the soils are very old and weathering in situ; they are very old and leached/weathered. This condition is further emphasised by the interpolated gama radiometric image shown in the centre of Fig. 7. Here, the layer has been modified to show those soils which are low in potassium, highlighting the boundaries between the highly leached soils (blue) and those soils that have higher nutrient holding capacity (red). This image is a further example demonstrating that the northern cleared areas of Monjebup North were not suited for agricultural practices (low nutrient levels, and poor nutrient holding capacity).

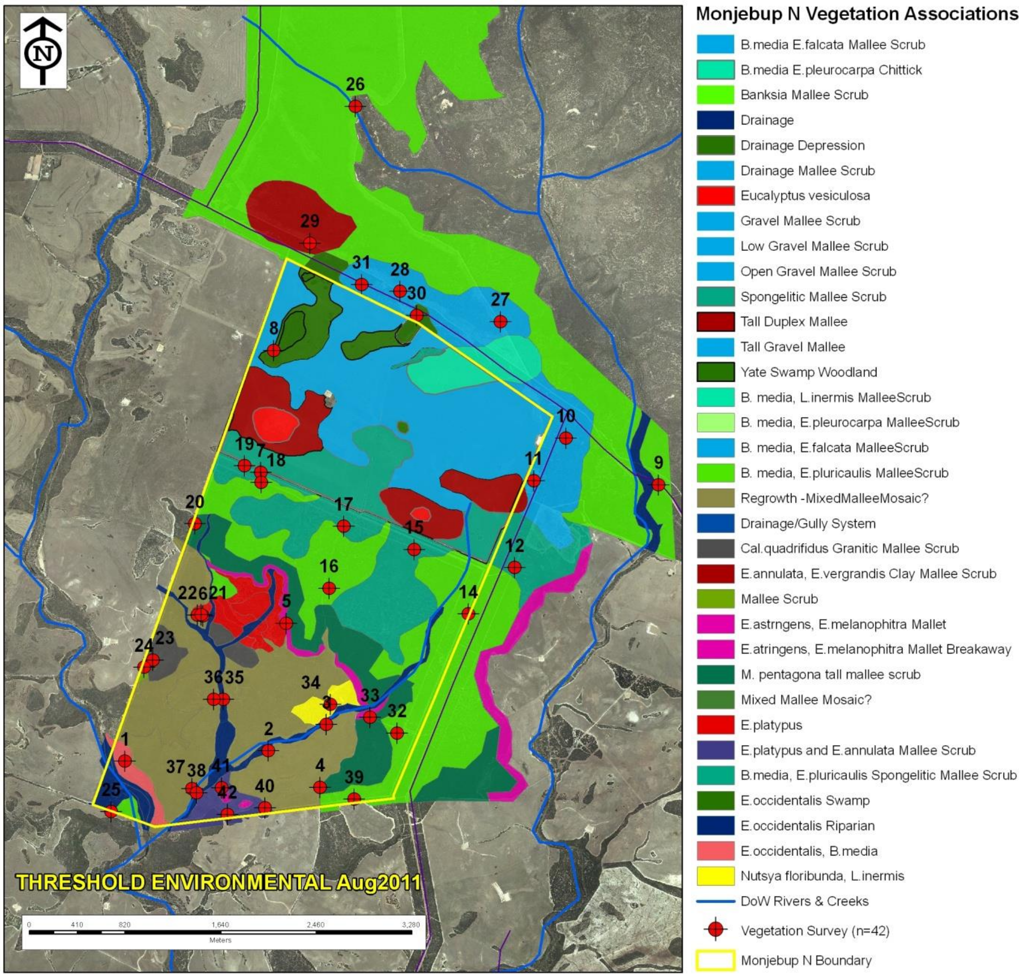
Referring to the available vegetation mapping for Monjebup North, the Newby Vegetation Map (shown as the right hand image in Fig. 7) provides some useful information at the landscape scale, but lacks the more detailed resolution of actual plant community boundaries at the patch/property scale. In this instance, the dominant vegetation type of the cleared portion of Monjebup North has been defined as the Epha or the *Eucalyptus phaenophylla* vegetation association. It is proposed, that this layer of the Newby mapping may represent an 'infill' layer (or last layer defined in the mapping process), as it provides the largest percentage of coverage (37%) for the Newby GIS layer, more than double the area of the next most prevalent vegetation association (see pie chart).



This condition is further emphasized as *Eucalyptus phaenophylla* is generally a ubiquitous species found in the majority of mallee vegetation associations across the Fitz-Stirling Landscape. This referral to the quality of available data highlights the need for rigorous site specific vegetation surveys prior to development of a ecological restoration plan.

The full analysis of vegetation associations found at Monjebup North is presented in the accompanying document, 'The Vegetation of Monjebup North'. A map of the distribution of vegetation associations, along with systems proposed for the cleared areas, is presented in Fig. 8. The image is a working map and serves to provide a broad view of the plant community mosaic at the sub-landscape scale. This is important as the site aims to reconnect the ecosystems that have become separated due to clearing. The light green 'Banksia Mallee Scrub' layer is a broad affiliation and ongoing analysis is recommended to further differentiate sub-systems within it.

Figure 8. Site Remnant Vegetation and Restoration Systems Map developed from on-ground data.

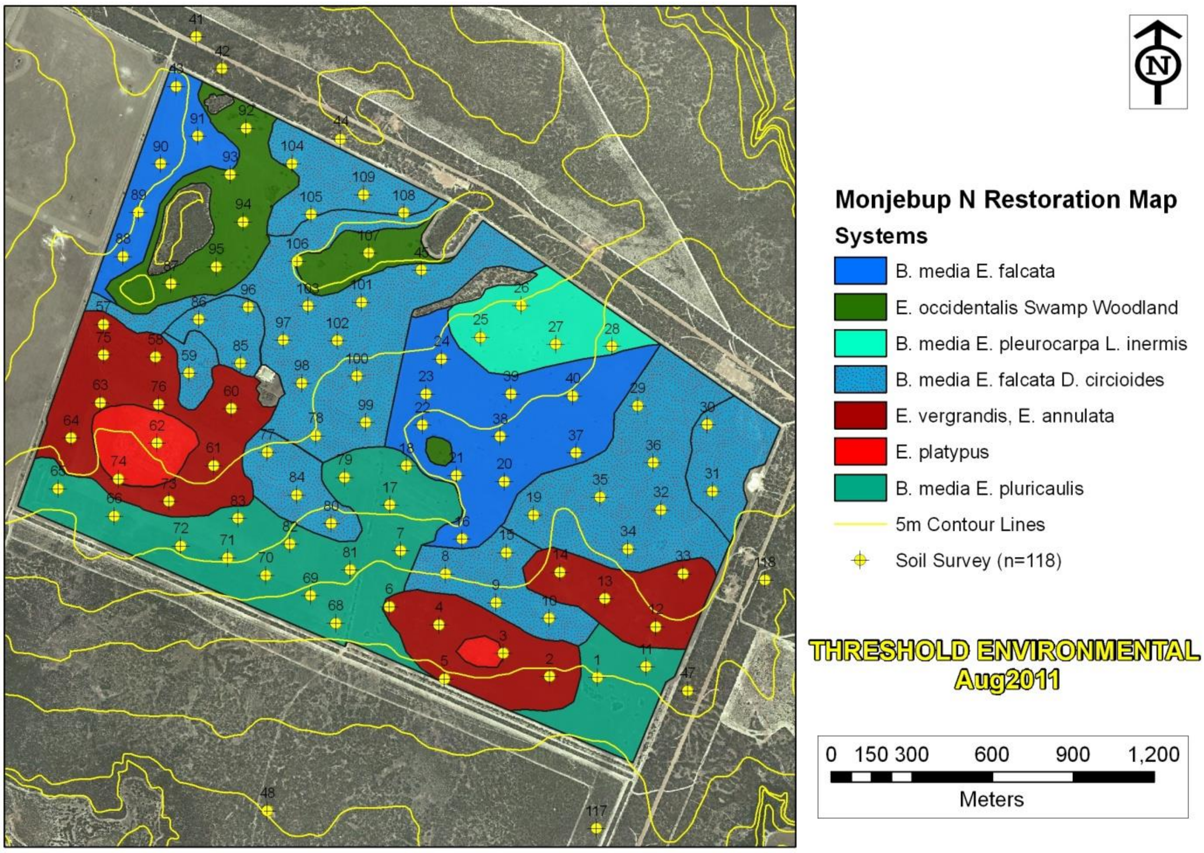


With each change in scale, the resolution of the area in focus is modified. As the scale of vision gets wider, small detail is lost in the broader fabric of the landscape. However, it is the broader fabric that enables the persistence of the detail within, most notably through the presence of a locally available seed source. Numerous biotic and aboitic filters have influenced the resulting species mixes through countless selections. The resulting assemblages observed are those which have survived the numerous state transitions that have arisen due to countless disturbances.

From a restoration perspective, preserving and enhancing the local patch scale mosaic that is nested within the broader landscape scale mosaic is likely to be the best way to conserve biodiversity in situ. Results from the vegetation survey show that plant diversity for the ~10 x 10m sampling units averaged approximately 18.4 species per location. However, across the entire site over 224 species were identified in total. This high turnover of species diversity is characteristic of the Fitz-Stirling mallee mosaic. It is also a condition that poses significant challenges for ecological restoration.

In order to restore at multiple scales, and preserve 'hot spots within the hot spot', a finer resolution of focus is required. In this case, refocusing on the approximately 400ha of cleared land slated for restoration at Monjebup North. Armed with information on plant community compositions and their spatial distribution, the soil mapping results were revisited to draw these two input variables together. Using this approach a more refined division of the broader vegetation units was undertaken. The layout shown in Fig. 9 indicates the extent and distribution of vegetation associations proposed for restoration at Monjebup North.

Figure 9. Paddock scale restoration map proposed for cleared areas.



Species mixes for each of the systems illustrated above should be informed by the vegetation association detail outlined in the accompanying document, ***The Vegetation of Monjebup North***. In those instances where a direct match is unavailable, hybrid systems which combine elements of two systems can be used. Brief descriptions of each of the proposed plant systems for restoration are outlined below. It should be noted that species composition and ultimate rates will reflect seed availability.

Fauna Focused Ecological Restoration

A restoration goal of fully reestablishing both the ecological structure and function that existed in a pre-cleared state is a challenging task in its self. This process begins with an effort to recreate plant communities in a broad mosaic that are well composed in species compositions, densities, and spatial distributions. Indeed, restoration ecology at larger scales is still not achieving these ends to their full capacity. However projects have been implemented where some of these ecological processes have been supplied at a broad level (Jonson 2010). For example structural and functional services can be achieved through the reestablishment of plant communities if they are 1) distributed across the site in varying plant densities, 2) have a good spread of different plant height stratums, 3) have sufficient species diversity to provide asynchronistic flowering, and 4) produce a variety of plant biomass materials for the provision of both food and shelter. In this way, the plants themselves, if configured in the appropriate composition and structural layout, can provide many of the resources required by fauna for food, shelter and protection. Specific examples of how they support local resident fauna are:

1) increase invertebrate populations (i.e. bugs) for consumption by insectivores and omnivores
2) provide floral resources (i.e. nectar) for consumption by nectarivores and omnivores

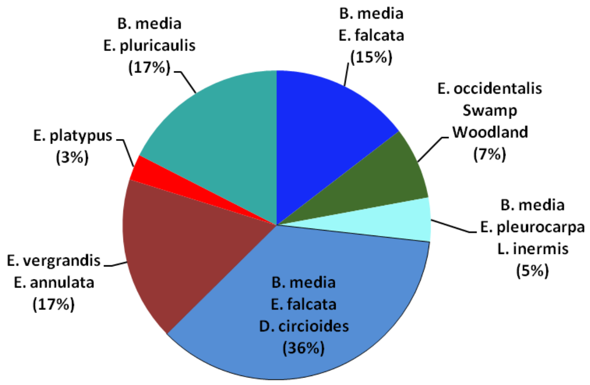
3) provide seed/fruit for consumption by granivores and omnivores
4) provide excess biomass (bark, litter) for nest construction
5) provide zones of high density vegetation (i.e. thickets) for provision of shelter/protection

However, in themselves, plant focused restoration fails to emphasise the specific habitat features known to support the local fauna. Rather than assume that plants provide habitat, the quality of the restoration is improved by focusing on fauna habitat quality, specifically with an effort to return the critical elements which facilitate survival and successful reproduction (Morrison 2002).

Restoration Systems

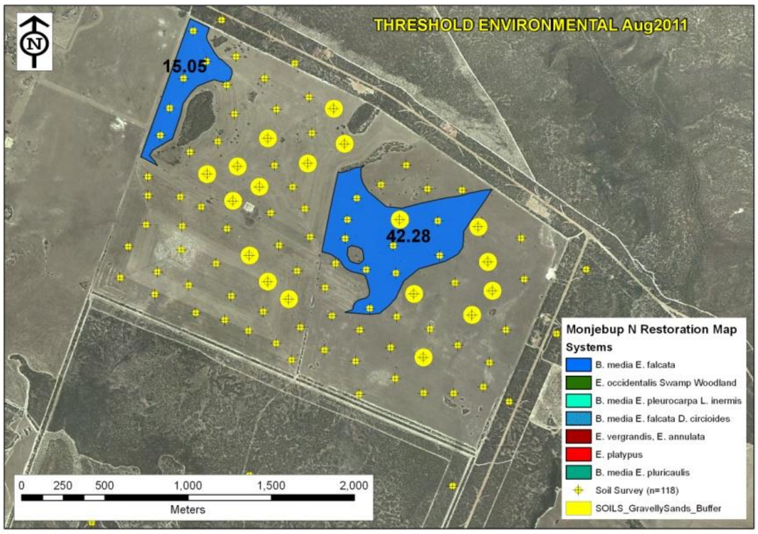
It is widely acknowledge in the field of ecological, that habitat variety allows for greater species diversity (Rosenzweig 1995). In addition, habitat quality is also known to play a major role in the ultimate use of an area by local faunal populations (Maschinski 2006, Munrow *et al.*, 2011).

A comprehensive assessment of the surrounding vegetation and soils results in the recommendation of 7 board restoration systems would be suitable for the cleared lands. It should be noted that the mapping and area calculation developed in this report are preliminary guides only. Although the soil sampling intensity of the cleared areas was high, the actual boundaries between the different systems defined will require further modification following soil disturbances such as ripping, scalping, or mounding activities. However, these preliminary area calculations will easily serve to inform the operational activities associated with seed and seedling requirements.



Through the establishment of the 7 broad restoration systems, a mosaic of different plant communities are re-created. These systems can then go on to provide discrete habitat zones with different functional attributes. Through the addition of specific habitat treatments (i.e. debris piles, thickets, grass and sedge patches, proteaceous nodes, etc.) the habitat qualities increase along with the services provided by the restored systems. While each individual system, or specific habitat treatment, can be viewed in isolation, it is the collective unit of restored heterogeneity that provides a contrast to 'mixed soup' revegetation.

Restoration System 1: *Banksia media* and *Eucalyptus falcata* Tall Closed Mallee Scrub
TOTAL AREA: 57.3 Hectares



This system is essentially a **MN1** type vegetation association (***Banksia media*, *Eucalyptus falcata*, & *Dryandra cirsioides* MalleeScrub)** however deeper soils shift the structural goals of the system away from the open type mallee scrub woodland with a significant low shrub/heath component, toward more of a tall mallee scrub type plant community. In this regard the upper structural layers should aim to be direct seeded primarily to E. falcata, E. captiosa, and E. thamnoides, and secondarily to E. pleurocarpa, E. phaenophylla, and E. uncinata. Depending on availability, mid and lower story species listed in the MN1 vegetation association should also be included in the direct seeding mix.

Seedlings propagated for the Proteaceae family should be hand planted. This includes both wide spaced individuals, and tighter closely planted 'nodes'.

Depending on seed availability, other species listed in the MN1 association should also be grown as seedlings and hand planted. Examples of this are Davesia lancifolia, the Baekeas, Callitris roeii, the Gompholobiums, and Santalum accuminatum.

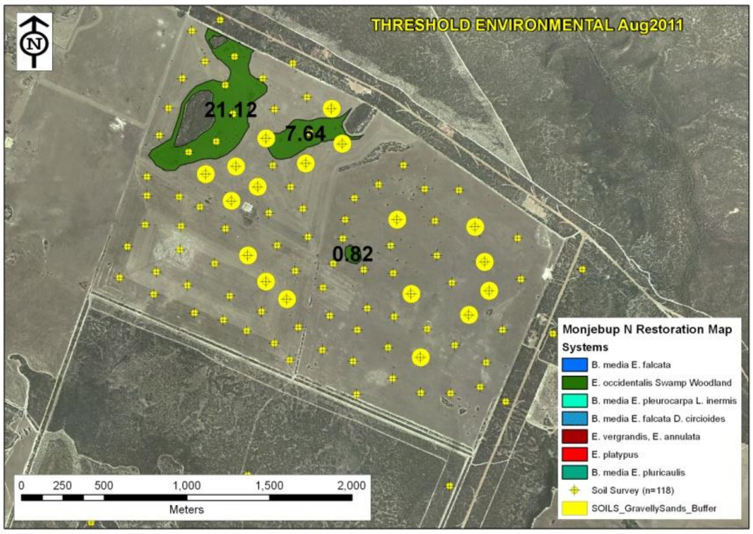
FAUNA ELEMENTS for Restoration System 1:

This restoration system should provide contrast to the surrounding restoration systems in its structural function as a tall closed mallee assemblage. Stem densities of the mixed Eucalypt mallee species for this system could range from 1000 to 2000 stems per hectare to achieve these ends. It is recommended that this is achieved through direct seeding, at rates of 250 to 300 grams per hectare. It is imperative that row spacing is below 1.5 meters for this establishment.

Additional species for this system, and the recommendations on which to direct seed and which to plant as seedlings are provided in Appendix B.

Heavier densities of the mid and upper story species will provide contrast to the more open mallee heath style vegetation assembles located adjacently.

Restoration System 2: YATE (*Eucalyptus occidentalis*) Swamp Woodland
TOTAL AREA: 29.6 Hectares



This system was not directly surveyed in the vegetation survey exercise, primarily because it was species poor due to years of access by sheep. However, the system should would be represented by many of the elements that are common to both the **MN7** (***Calistemon phoeniceus, Melaleuca accuminata & Mixed sp.*** **Drainage**) and **MN10** (***Eucalyptus occidentalis / Banksia media*** **Riparian Woodland Scrub**) type vegetation associations.

The upper structure sytem is dominated by *Eucalyptus occidentalis*, which should be direct seeded. For the areas slated for restoration into Yate Swamps for Monjebup North, the underlying soil type has a distinct ironstone gravel influence, and therefore species which are affiliated with these systems can also be supplemented at low rates. Examples of these were noted in the system described above. Mid and lower-story species such as *Acacia saligna*, *Calistemon phoeniceus* and *Melaleuca accuminata* should be included in direct seeding, along with water loving Melaleucas, such as *Melaleuca hamulosa*. Seedlings propagated for the Proteaceae family such as *Hakea laurina* should be widely spaced across the system by hand planting. This is generally not a species rich association.

FAUNA ELEMENTS for Restoration System 2:

The Yate Swamp Woodland restoration system is located in an area which is subject to broad flooding following large rainfall events (Geoff Plain personal communication). The system has specific relevance to fauna in that it represents a tall open woodland habitat. Yate (*E. occidentalis*) trees would ideally be positioned in a widely spaced open arrangement, with goal densities ranging from 100 to 200 stems per hectare. In this regard, it may be useful to consider the establishment of the Yate trees through seedlings to control the resulting stem densities, while including small quantities of Yate seed in the direct seeding mix to provide the added randomness. For a full breakdown on seedlings versus direct seeding for this system, see Appendix B.

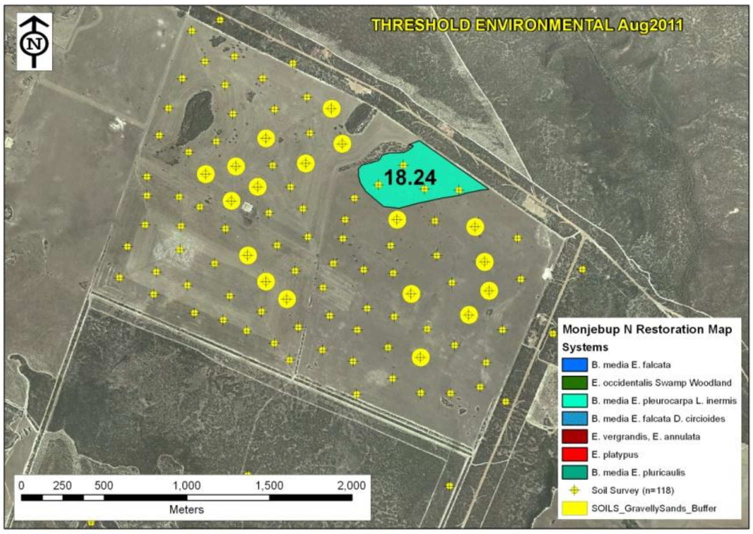
As the system is underlain by shallow gravelly sands, supplemental seedlings from the proteaceous family will be well suited to this system. In addition to short lived acacia species, some of the longer lived mid story trees (i.e. *Acacia microbotrya*, *Acacia cyclops* and *Allocasuarina heugeliana*) should also be established at similar densities to the Yate to provide mid-structural elements.

A resulting open woodland layout with some added thickets of *Melaleuca accuminata* established in large scalped areas and brush-mulching, will be preferred. Such open layouts are also of high suitability for habitat debris piles of various compositions.

If possible, large hollow logs, or alternatively large second hand drainage pipes, can be used in conjunction with debris piles to increase the habitat shelter elements for local mammal and reptile species.

Restoration System 3: *Banksia media, Eucalyptus pleurocarpa* and *Lamberitia inermis* Open Mallee Scrub

TOTAL AREA: 18.24 Hectares



This system is essentially a hybrid between the **MN1** (***Banksia media, Eucalyptus falcata, & Dryandra cirsioides*** **MalleeScrub)** and the **MN9** (***Nutsya floribunda / Lambertia inermis*** **Mallee Scrub**) type vegetation associations. The reason for this is that the soils in this unit have a deeper sandy soil 'A horizon' than any of the other cleared areas. However, they also have a gravel affiliation as well. The area has a few remnant mallees remaining which are almost all *Eucalyptus falcata*. Largely exposed lignotubers suggest these areas may have previously held deeper 'A horizon' profiles. This system should be planted out on the richer side for species from the Proteaceae family. The final assemblage for this system should aim to be a closed shrub with an open over-story component.

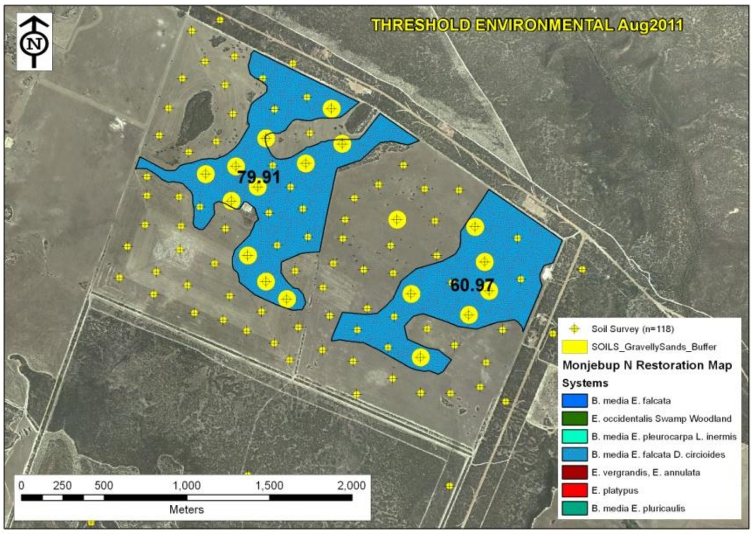
FAUNA ELEMENTS for Restoration System 3:

A strong focus on the mid-story vegetation layer should be made for this system. Over-story species should be implemented at lower densities (200 to 300 stems per hectare). The lower understory species can also be seeded at a relatively high level, but it is the mid story species that will likely dominate this area.

Establishment of a dense shrubby mid-story layer is one of the easier treatments to achieve through direct seeding. For this process, it is recommended that seed row spacing is less that 1.5m on center to avoid highly stocked rows. While specific information to inform seeding rates of the target mid-story species for this system are not available, broad total rates of 150 to 200 grams per hectare of the finer seeded species (i.e. species of the Melaleuca, Kunzea, and Calothamnus genera) will provide good coverage.

A full breakdown on seedlings versus direct seeding for this system is listed in Appendix B.

Restoration System 4: *B. media*, *E. falcata*, and *Dryandra circioides* Mallee Scrub
TOTAL AREA: 140.9 Hectares



This system has been clearly outlined as **MN1** (***Banksia media*, *Eucalyptus falcata*, & *Dryandra cirsioides* Mallee Scrub**) in *The Vegetation of Monjebup North* accompanying document.

Key issues to be aware of for this system are the gravely sandy soils which are well suited for supplemental seedlings of *Dryandra circioides* within this broader system. The identification of these areas was made possible through the level of detail executed within the soil survey. In the image above, areas which are best suited for *Dryandra circioides*, and other gravel loving Proteaceous species have been identified with 1 Ha buffers (larger yellow circles). Additional species to include are *Hakea corymbosa*, *Hakea pandanicarpa*, *Hakea trifucata*, *Dryandra nervosa*, and *Isopogon trilobus*.

A number of different supplemental seedling densities can be employed to provide the desired ecological structure and functional attributes. A goal of reestablishing individual sub-populations of 150 to 200 plants from one species would be a very good result. Consideration of the growth form for each of the species planted as supplemental seedlings can help inform their spacing. Previous results suggest that low spacing (<1.5m) between individual plants may provide improved structure in the short to medium term as the plants mature.

FAUNA ELEMENTS for Restoration System 4:

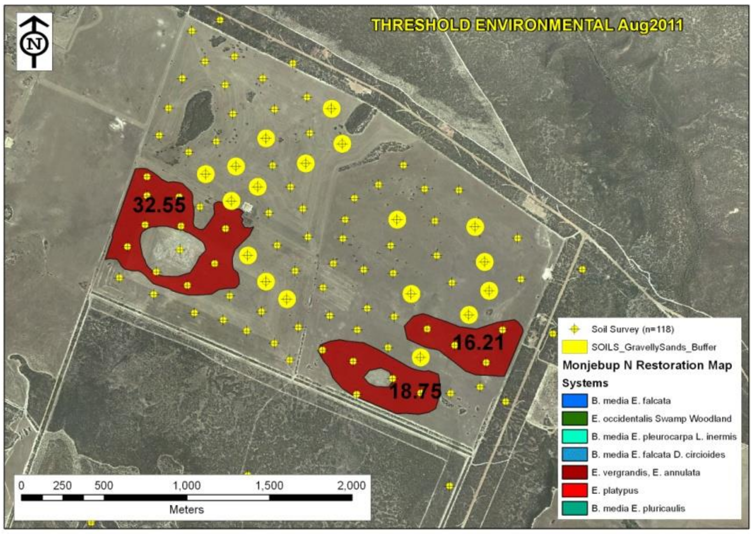
This system is the largest restoration association proposed for the cleared areas of Monjebup N, making up approximately 36% of the total project area. Structurally this restoration system should aim to recreate a tight low understory of Melaleuca shrubs, most notably *M. spathulata*, *M. bracteosa*, *M. violacea*, *M. carrii* and *M. tuberculata*. A challenge exists for the operational delivery if the full replication of the low, tight, heath formation present in the adjacent vegetation is sought.

Incorporation of additional understory Acacia species is recommended for this restoration system. These to include *Acacia pulchella ssp. goadbyi*, *A. myrtifolia*, *A. lasiocarpa ssp bracteolate*, and *A. newbeyi*. All four of these species are not generally very competitive with other plants, but are short lived, provide large quantities of litter, and occupy a low strata in the plant community structure.

Consideration of incorporating some large scalped areas with seed mulch or brush mulching in thin layers may also be considered for this restoration system.

In addition to the Proteaceous species indicated above, the inclusion of Hakea lissocarpa should also be considered. This species provides green fruit pods which are of notable value as a food source for the Carnaby's Black Cockatoo.

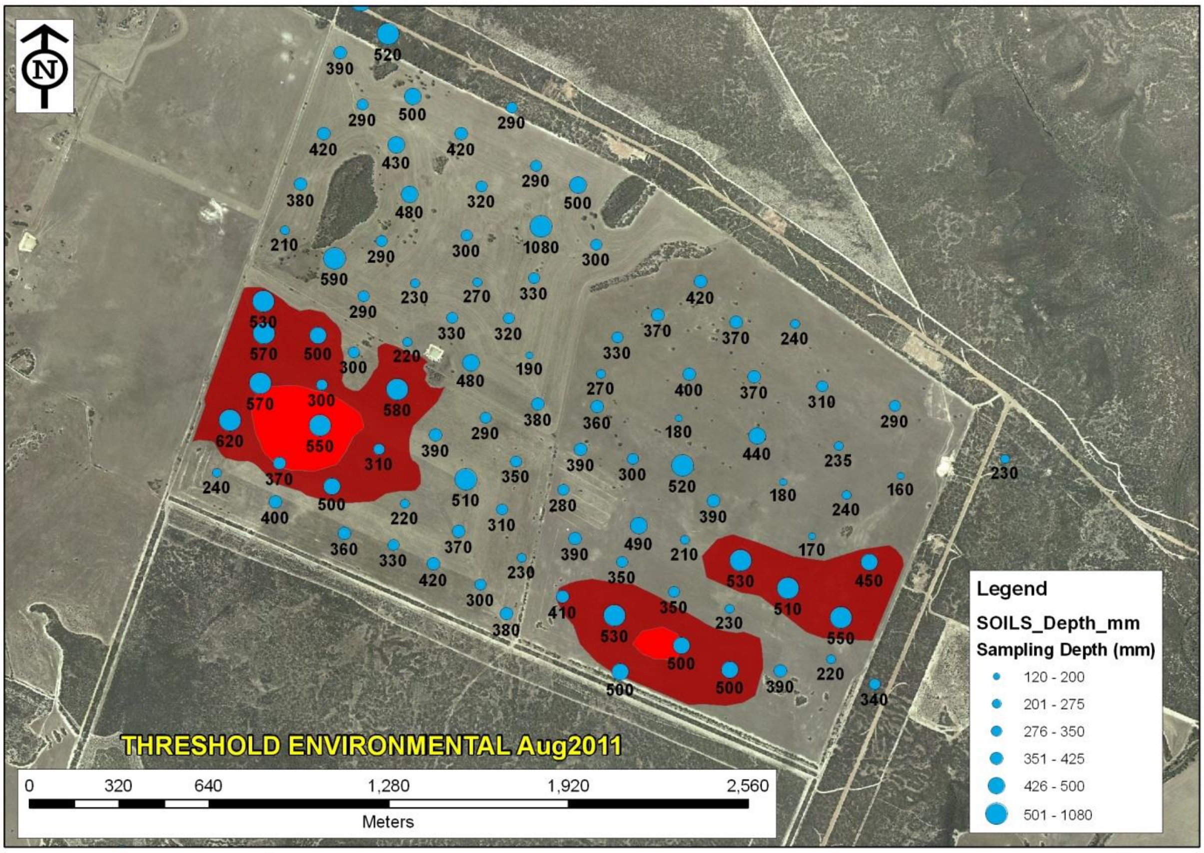
Restoration System 5: *Eucalyptus vergrandis, Eucalyptus annulata,* and *Eucalyptus conglobata* Tall Closed Clay Mallee Scrub
TOTAL AREA: 67.5 Hectares



This system has been clearly outlined as **MN3** (***Eucalyptus annulata, Eucalyptus vergrandis & Eucalyptus conglobata***) in *The Vegetation of Monjebup North* accompanying document.

This system is essentially a Tall Mallee Scrub type plant community over a medium clay soil type. It is in these systems that soil friability was greatest, and soil auger sampling was able to easily go to depth. The image in Fig. 11 shows how soils for this system are associated with ease of excavation, as demonstrated by the available sampling depth in the soil survey exercise. These systems are likely to be quite productive and can therefore support a dense assemblage of vegetation. It should also be noted that these system are difficult to achieve robust establishment on through direct seeding and therefore additional seedling planting should be considered.

Figure 11. Location of restoration system #5 in relation to soil pit depth data.

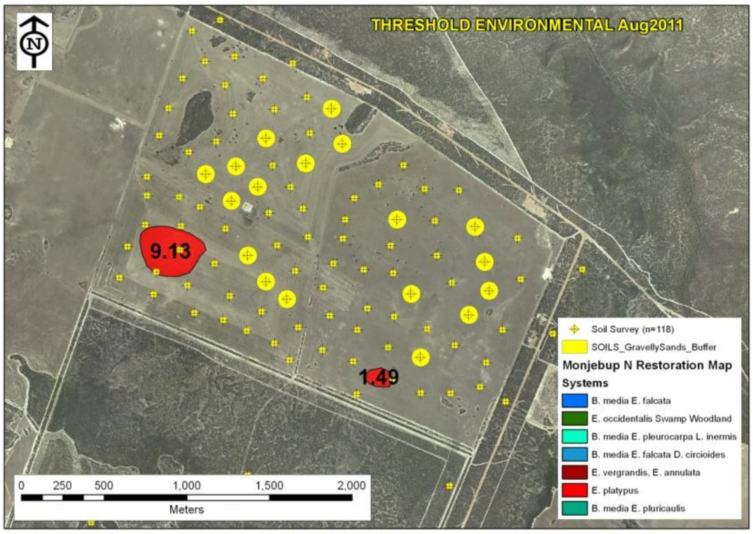


FAUNA ELEMENTS for Restoration System 5:

As indicated above, and pointed out by Bush Heritage Ecologist Angela Sanders, the restoration systems which have best cultivation capacity are those which are likely to suit occupancy by burrowing fauna. To encourage this activity, one approach may be to establish a number of habitat debris piles (see in later section) to provide shelter and sites of interest for those burrowing animals.

Another aspect to consider for this restoration system is the incorporation of water retention zones, through the establishment of contour catchment banks, or small excavated depressions in strategically located positions.

Restoration System 6: MOORT (*Eucalyptus platypus*) Low Closed Woodland
TOTAL AREA: 10.6 Hectares



This system has been clearly outlined as **MN4** (***Eucalyptus platypus / Eucalyptus vesiculosa Woodlands***) in *The Vegetation of Monjebup North* accompanying document.

Of note for this system is the option for use of *Eucalyptus platypus* sub species *platypus* ('Moort'), or alternatively *Eucalyptus vesiculosa* ('Red Flowering Moort') for these areas. Generally, it has been observed that *E. vesiculosa* has an affiliation for moisture gaining sites. However, it is a species which is endemic to the local landscape, and has been observed both on and around Monjebup North. As the areas proposed for this system are relatively small in extent, and are in locations in which moisture is available, *E. vesiculosa* could be planted in these areas. Alternatively, *E. platypus* could be planted. Whichever is sought, it is recommended that a combination of both tightly spaced trees (>2500 stems/ha), and widely spaced trees (<500 stems/ha) be established to promote a diverse structure. This can also be achieved through following establishment techniques that use a combination of direct seeding and seedlings.

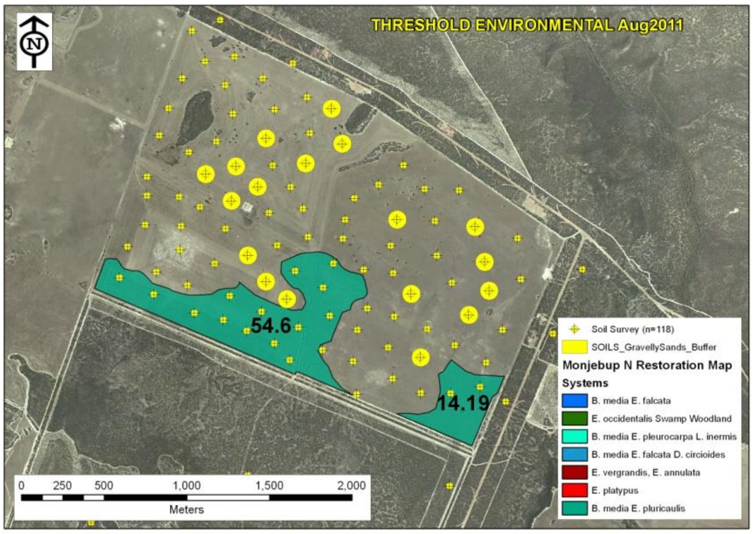
FAUNA ELEMENTS for Restoration System 6:

Moort vegetation associations are well known for their ability to produce a substantial level of plant litter material as they grow. This litter supports increases in invertebrate populations and associated vertebrate predators.

Such high levels of litter production can also benefit the Mallefowl, as materials can be drawn from within the Moort system into mallee systems growing adjacently.

Old growth Moort systems are also known to produce hollows in their main trunks. While this does take a long time, it is good that the wide spaced individuals are included in the planting design to help facilitate the development of this habitat feature in time.

Restoration System 7: *Banksia media and Eucalyptus pluricaulis* Mallee Scrub
TOTAL AREA: 68.8 Hectares



This system has been clearly outlined as **MN2** (**Banksia media, Eucalyptus pleurocarpa, & Eucalyptus pluricaulis Mallee Scrub**) in *The Vegetation of Monjebup North* accompanying document.

Similar to the restoration system 4, this system is one of the common assemblages at Monjebup North. Key factors to note for this association are the dense understory of Melaleuca heath that occurs within it. Large quantities of seed will be required to achieve these outcomes. In addition, seeding rows will need to be relatively close together to achieve the tight structure demonstrated in the remnant vegetation.

FAUNA ELEMENTS for Restoration System 7:

Eucalyptus pluricaulis ssp. porphorea produces prolific flowers during the autumn food gap.

Fauna focused detail within the Restoration Systems

A restoration goal central to this planning project has been to define on-ground treatments to restore the habitat qualities which support local resident faunal species (n = 146).

From the analysis of the fauna requirements at Monjebup North (Sanders 2010), assessments of the proposed restoration systems can be undertaken to ensure that resident fauna is supported. As discussed, this should include both broad (i.e. understory vegetation) and specific (i.e. hollow logs) habitat provision.

The restoration of cleared areas at Monjebup N should not be perceived as a 'one off' event, and ongoing treatments will be required if all the resource requirements of the resident fauna species are to be met. While some habitat resources can be developed through broad treatments, other more species specific treatments, which are beyond the scope of this planning exercise, can be applied over time.

Further emphasis to specific trophic level relationships, and niche requirements of resident fauna, can be defined and accommodated at a species specific level. This process will be best achieved through the identification of a smaller target species. It is unlikely that every single habitat condition can be known for each species, and therefore the restoration of fauna habitat resources should be understood as a process that requires planning over a number of years. For example, recent focused efforts on the Tammar Wallaby (*Macropus eugenii derbianus*), a target species identified in the Fitz-Stirling Functional Landscape Plan (FLP) were still only able to provide general recommendations as to the specific habitat requirements for that species. Indeed, such investigations are complex and difficult to unravel. However some broad recommendations from this research (i.e. 60%+ ground cover; <200m away from mallee woodlands) can be of reference when planning the on ground works (Tulloch 2010).

Asynchronistic flowering

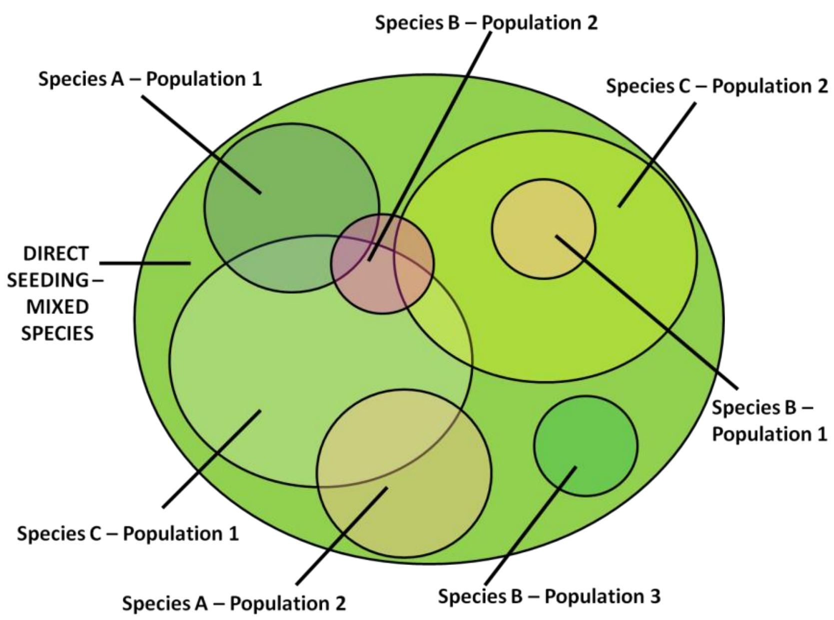
In order to achieve asychronistic flowering, a diversity of species will need to be established across the site. This is of great importance for the large and small resident nectarivores which make up 3% and 13% of the total local avifauna respectively (~14 species in total). While some information is available on flowering times of the local flora, variations due to local climatic factors and differences in flowering times/occurrences (even locally within a single species), suggest the best approach is to aim to re-establish as many plant species as possible. Incorporating large numbers of plants from the Myrtaceae and Proteaceae families also ensures that reestablished flora provides sufficient nectar resources throughout the year.

Results from previous restoration projects indicate that only a certain subset of the flora species available are easily able to establish through direct seeding. As a result, a strong emphasis on increasing plant species diversity through the establishment of a tightly coordinated supplemental seedling treatment. This approach was demonstrated in part by Jonson (2010) through the implementation of 'Proteaceous Nodes', 'Sandalwood Nodes', and 'Hand Broadcast Seed Nodes', but there is much room for improving on this approach in the Monjebup N restoration project.

Proteaceous plants provide nectar to fauna in the autumn food gap, a period during each year when food resources are low. **Supplemental seedlings** for those species which are hard to germinate or produce small amounts of seed (i.e. Banksia, Dryandra, Grevillea, Hakea) should be the priority for these activities.

The eventual number and distribution of these supplemental seedling populations will directly reflect seedling availability, due to time constraints and difficulty in propagation. The eventual placement and densities implemented for each species set of supplemental seedlings should also reflect the faunal focus of the project. This includes consideration of individual species attributes such as forage and dispersal patterns, and the habitat attributes sought for their success (Morrison 2002). In addition, supplemental seedling patches can increase the structural complexity, for example through the establishment of tightly spaced plantings. A broad visual map to serve as a guideline has been shown in Fig. 12.

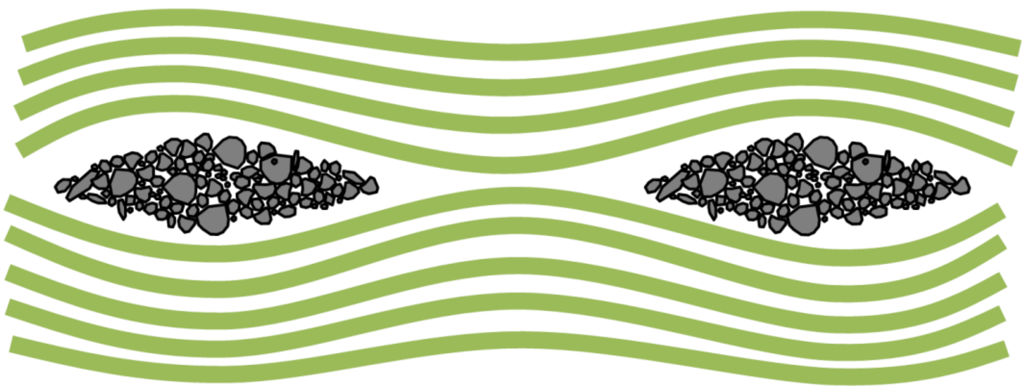
Figure 12. Demonstrated layout for augmentation seedlings.



In addition to supplemental seedlings to increase species diversity, and facilitate inclusion of species for which large quantities of seed are unavailable, a number of other treatments are also prescribed. These include habitat debris piles, contour water catchment banks, and brush mulched patches. These treatments, in combination with supplemental seedlings and a diverse mosaic of different restoration systems, will markedly improve the habitat features favorable for the local fauna.

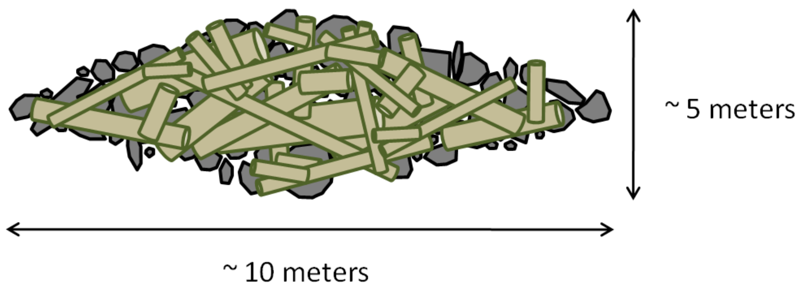
The integration of these treatments should be made on the contour and not interfere too greatly with the operational aspects of the direct seeding. An example of this sort of spatial arrangement is shown in Fig. 13, where piles are elliptical in shape.

Figure 13. Suggested layout of habitat features in line with direct seeding operations.

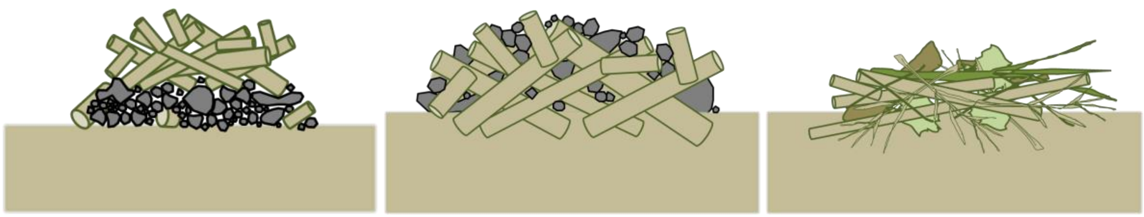


Although many different combinations of material are suitable for creation of these habitat features, a few design options have been proposed for consideration.

Figure 14. Potential Habitat Debris Pile dimensions



Design Concepts: The following illustrations provide a visual demonstration of potential habitat debris pile designs. Utilizing resources in different concentrations and configurations, the three suggested designs are likely to provide different habitat qualities for local fauna. In the left hand image, woody materials are positioned above the soil surface perched on rocks to delay decomposition. This sort of design may suit the smaller reptiles. The center design features a mix of branches and rocks; this sort of habitat debris feature may promote conditions suitable for medium to large burrowing animals (e.g. Short-beaked Echidna). The pile displayed in the right hand image is mainly composed of branch and vegetative 'slash'; this sort of debris pile may facilitate elements connected with decomposition, boosting invertebrate activity and associated resources.



In addition to the habitat debris piles, supplemental plantings of the sedges, rushes, and grasses can improve the delivery of a restored ecosystem. This activity will also contribute to achieving goals of the full compositional and structural diversity of a native ecosystem. Such ground level flora has often been left out of the broad acre direct seeding projects, as viable seed is difficult to harvest, and techniques for reestablishment have not been developed at such scales. Through the use of tissue culture techniques or transplanting existing stock on site, these systems can been re-established on the cleared land. In this circumstance, the goal is to reduce the time required for the target plants to re-colonize the cleared land. It is assumed that the majority of new recruitment occurs through rhizome growth, division and subsequent propagation. While the best density for re-establishment is not known, a reasonable goal may be to establish a node of 20 to 50 plants every 3 hectares, but other densities could be explored.

While large trees and shrubs are often the focus of revegetation works, more optimal biodiversity values can be achieved through inclusion of patches of **rushes** and **sedges** (*Juncus sp*., *Isolepis sp*., *Cordifex sp*., *Desmocladus sp*.) throughout the site.

FINAL STATEMENTS:

Ecological restoration is a practice that requires constant review of resource availability in the context of project goals. It is an information rich arena in which attention to detail and strong record keeping enhance the capability of project participants to deliver the best possible outcomes. There is no upper limit of effort when restoring at the paddock (100ha +) scale. For each project, many opportunities exist to make incremental gains toward improving the ecological function of a given restoration area. Ongoing review of ecological principals, and ongoing development of innovative approaches to apply them, is best practice for restoration.

This plan is presented in 4 parts to provide a solid foundation of information and recommendations from which the on ground implementation can proceed. Ecological restoration is a process in which both biotic and aboitic information is gathered, analysed, and applied. This process is not static, and requires multi-disciplinary thinking to fully realise the restoration potential of the site.

This plan is not a prescriptive recipe for 'how to restore an area of land in the Fitz-Stirling landscape', but rather a comprehensive planning document to guide the restoration team through on-ground implementation.

Full effort in the execution of the on-ground restoration can achieve unexpected results. The consultant wishes those who implement this plan the best of success.

"Big whorls have small whorls that feed on their velocity, and small whorls have lesser whorls and so on to viscosity"

-Lewis Fry Richardson

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APPENDIX A: Fauna presence data for 146 species identified in Bush Heritage fauna survey work at the Monjebup (MON), Monjebup North (MONN), Chingarup (CHN), Nowanup (NOW), Chereninup (CHE), and Peniup (PEN) sites within the Fitz-Stirling pathway. Data provided by Bush Heritage Ecologist Angela Sanders.

Fauna Recorded during BHA survey work		MON	MONN	CHN	NOW	CHE	PEN
BIRDS							
CASUARIIDAE	**Large Flightless Birds**						
Dromaius novaehollandiae	Emu	1	1	1	1	1	1
MEGAPODIIDAE	**Mound Builders**						
Leipoa ocellata	Malleefowl	1		1	1	1	
PHASIANIDAE	**True Quail**						
Coturnix pectoralis	Stubble Quail	1			1	1	1
ANATIDAE	**Ducks**						
Tadorna tadornoides	Australian Shelduck					1	1
Chenonetta jubata	Australian Wood Duck					1	1
Anas gracilis	Grey Teal					1	
Anas castanea	Chestnut Teal	1		1		1	1
Anas superciliosa	Pacific Black Duck	1		1		1	1
PODICIPEDIDAE	**Grebes**						
Tachybaptus novaehollandiae	Australasian Grebe			1			
Poliocephalus poliocephalus	Hoary-headed Grebe	1					1
PHALACROCORACIDAE	**Cormorants**						
Phalacrocorax melanoleucos	Little Pied Cormorant					1	1
Phalacrocorax sulcirostris	Little Black Cormorant					1	
PELECANIDAE							
Pelecanus conspicillatus	Australian Pelican			1			
ARDEIDAE	**Herons, Egrets & Bitterns**						
Ardea pacifica	White-necked Heron						
Ardea novaehollandiae	White-faced Heron	1		1		1	1
Nycticorax caledonicus	Rufous Night Heron						1
THRESKIORNITHIDAE	**Ibises & Spoonbills**						
Threskiornis molucca	Australian White Ibis						
Platalea flavipes	Yellow-billed Spoonbill						
ACCIPITRIDAE	**Kites, Eagles & Hawks**						
Elanus caeruleus	Black-shouldered Kite					1	1
Hamirostra isura	Square-tailed Kite					1	
Haliastur sphenurus	Whistling Kite			1			1
Accipiter fasciatus	Brown Goshawk						
Accipiter cirrhocephalus	Collared Sparrowhawk					1	
Aquila morphnoides	Little Eagle						
Aquila audax	Wedge-tailed Eagle	1	1	1	1	1	1
Circus assimilis	Spotted Harrier						
Circus approximans	Swamp Harrier						
FALCONIDAE	**Falcons**						
Falco berigora	Brown Falcon	1		1	1	1	1
Falco cenchroides	Australian Kestrel	1		1	1	1	1
Falco longipennis	Australian Hobby	1			1		1
Falco peregrinus	Peregrine Falcon			1	1	1	
RALLIDAE	**Rails & Crakes**						
Gallinula ventralis	Black-tailed Native-hen						
Fulica atra	Eurasian Coot			1			1
OTIDIDAE	**Bustard**						

		MON	MONN	CHN	NOW	CHE	PEN
Ardeotis australis	Australian Bustard						
TURNICIDAE	**Button-quail**						
Turnix varia	Painted Button-quail	1	1	1	1	1	
BURHINIDAE	**Stone-curlews**						
Burhinus grallarius	Bush Stone-curlew						
CHARADRIIDAE	**Wading Birds**						
Vanellus tricolor	Banded Lapwing	1					1
Charadrius melanops	Black-fronted Dotterel						
COLUMBIDAE	**Pigeons & Doves**						
Phaps chalcoptera	Common Bronzewing	1		1	1	1	1
Phaps elegans	Brush Bronzewing	1			1	1	
Ocyphaps lophotes	Crested Pigeon	1		1	1	1	1
PSITTACIDAE	**Parrots**						
Calyptorhynchus latirostris	Carnaby's Cockatoo			1	1	1	1
Cacatua roseicapilla	Galah	1		1	1	1	1
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	1		1	1	1	1
Polytelis anthopeplus	Regent Parrot	1			1	1	1
Barnardius zonarius	Australian Ringneck	1	1	1	1	1	1
Purpureicephalus spurius	Red-capped Parrot	1		1	1	1	1
Platycercus icterotis	Western Rosella	1				1	
Neophema elegans	Elegant Parrot	1				1	1
CUCULIDAE	**Cuckoos**						
Cuculus pallidus	Pallid Cuckoo					1	
Cacomantis flabelliformis	Fan-tailed Cuckoo	1		1		1	1
Chrysococcyx basalis	Horsfield's Bronze Cuckoo	1		1	1	1	1
Chrysococcyx lucidus	Shining Bronze Cuckoo	1		1		1	1
Chrysococcyx osculans	Black-eared Cuckoo					1	
STRIGIDAE	**Owls**						
Ninox novaeseelandiae	Boobook Owl	1		1	1		
TYTONIDAE	**Owls**						
Tyto alba	Barn Owl						1
PODARGIDAE	**Frogmouths**						
Podargus strigoides	Tawny Frogmouth	1			1		
CAPRIMULGIDAE	**Nightjars**						
Eurostopodus argus	Spotted Nightjar	1		1	1	1	
AEGOTHELIDAE	**Owlet Nightjars**						
Aegotheles cristatus	Australian Owlet-nightjar	1		1			1
HALCYONIDAE	**Kingfishers**						
Dacelo novaeguineae	Laughing Kookaburra	1				1	1
Todiramphus sanctus	Sacred Kingfisher	1		1	1	1	1
MEROPIDAE	**Bee-eaters**						
Merops ornatus	Rainbow Bee-eater	1		1		1	1
MALURIDAE	**Wrens**						
Malurus splendens	Splendid Fairy-wren	1		1	1	1	1
Malurus pulcherrimus	Blue-breasted Fairy-wren	1		1	1	1	1
Stipiturus malachurus	Southern Emu-wren				1		
PARDALOTIDAE	**Small Bush Birds**						
Pardalotus punctatus	Spotted Pardalote	1	1	1	1	1	1
Pardalotus striatus	Striated Pardalote	1		1		1	1

		MON	MONN	CHN	NOW	CHE	PEN
ACANTHIZIDAE							
Sericornis frontalis	White-browed Scrubwren	1	1	1	1	1	1
Hylacola cauta	Shy Groundwren (Shy Heathwren)			1	1	1	
Calomanthus campestris	Rufous Fieldwren					1	1
Pyrrholaemus brunneus	Redthroat						
Smicrornis brevirostris	Weebill	1	1	1	1	1	1
Gerygone fusca	Western Gerygone	1		1		1	
Acanthiza apicalis	Broad-tailed Thornbill (Inla	1	1	1	1	1	1
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	1	1	1	1	1	1
MELIPHAGIDAE	**Honeyeaters**						
Lichmera indistincta	Brown Honeyeater	1		1	1	1	1
Lichenostomus virescens	Singing Honeyeater	1	1	1	1	1	1
Lichenostomus ornatus	Yellow-plumed Honeyeater					1	1
Lichenostomus cratitius	Purple-gaped Honeyeater	1	1	1	1	1	1
Lichenostomus leucotis	White-eared Honeyeater	1	1	1	1	1	1
Melithreptus brevirostris	Brown-headed Honeyeater	1		1	1	1	1
Melithreptus chloropsis	Western White-naped Honeyeater			1	1	1	1
Phylidonyris novaehollandiae	New Holland Honeyeater	1	1	1	1	1	1
Phylidonyris nigra	White-cheeked Honeyeate	1		1	1	1	
Phylidonyris melanops	Tawny-crowned Honeyeate	1		1	1	1	1
Acanthorhynchus superciliosu	Western Spinebill	1		1		1	1
Manorina flavigula	Yellow-throated Miner					1	1
Anthochaera hamulata	Western Little Wattlebird			1	1		
Anthochaera carunculata	Red Wattlebird	1	1	1	1	1	1
Ephthianura albifrons	White-fronted Chat		1	1	1	1	1
PETROICIDAE	Robins						
Petroica multicolor	Scarlet Robin					1	1
Petroica goodenovii	Red-capped Robin					1	1
Petroica cucullata	Hooded Robin						
Eopsaltria australis	Western Yellow Robin	1	1			1	
Drymodes brunneopygia	Southern Scrub-robin	1		1	1	1	1
POMATOSTOMIDAE	**Babblers**						
Pomatostomus superciliosus	White-browed Babbler	1		1	1	1	1
CINCLOSOMATIDAE	**Whipbirds & Quail-thrushes**						
Psophodes nigrogularis	Western Whipbird	1	1	1	1	1	1
NEOSITTIDAE	**Sittellas**						
Daphoenositta chrysoptera	Varied Sittella	1		1	1	1	1
PACHYCEPHALIDAE	**Whistlers & Shrike-thrushes**						
Oreoica gutturalis	Crested Bellbird			1	1	1	1
Pachycephala pectoralis	Golden Whistler	1	1	1	1	1	1
Pachycephala rufiventris	Rufous Whistler	1		1		1	1
Colluricincla harmonica	Grey Shrike-thrush	1	1	1	1	1	1
DICRURIDAE	**Flycatchers**						
Myiagra inquieta	Restless Flycatcher	1		1		1	1
Rhipidura fuliginosa	Grey Fantail	1	1	1	1	1	1
Rhipidura leucophrys	Willie Wagtail	1		1	1	1	1
Grallina cyanoleuca	Magpie-lark	1		1		1	1
CAMPEPHAGIDAE	**Cuckoo-shrikes & Trillers**						
Coracina novaehollandiae	Black-faced Cuckoo-shrike	1	1	1	1	1	1

		MON	MONN	CHN	NOW	CHE	PEN
Lalage triclolor	White-winged Triller	1		1		1	1
ARTAMIDAE							
Artamus cinereus	Black-faced Woodswallow	1				1	1
Artamus cyanopterus	Dusky Woodswallow	1		1		1	1
CRACTICIDAE							
Cracticus nigrogularis	Pied Butcherbird	1					
Cracticus torquatus	Grey Butcherbird	1	1	1	1	1	1
Cracticus tibicen	Australian Magpie	1	1	1	1	1	1
Strepera versicolor	Grey Currawong	1	1	1	1	1	1
CORVIDAE	**Ravens & Crows**						
Corvus coronoides	Australian Raven	1	1	1	1	1	1
HIRUNDINIDAE	**Swallows & Martins**						
Cheramoeca leucosternum	White-backed Swallow						
Hirundo neoxena	Welcome Swallow	1		1	1	1	1
Hirundo nigricans	Tree Martin	1			1	1	1
Hirundo ariel	Fairy Martin						
ZOSTEROPIDAE	**White-eyes**						
Zosterops lateralis	Silvereye	1	1	1	1	1	1
SYLVIIDAE	**Songlarks**						
Cinclorhamphus cruralis	Brown Songlark				1		1
PASSERIDAE	**Finches**						
Stagnopleura oculata	Red-eared Firetail	1		1			1
MOTACILLIDAE	**Pipits & Wagtails**						
Anthus australis	Australian Pipit	1		1	1	1	1
TOTALS FOR EACH PROPERTY		**78**	**26**	**75**	**63**	**91**	**85**
MAMMALS							
TACHYGLOSSIDAE	**Egg-laying Mammals**						
Tachyglossus aculeatus	Short-beaked Echidna		1	1	1	1	1
DASYURIDAE	**Carnivorous Marsupials**						
Dasyurus geoffroii	Chuditch						
Parantechinus apicalis	Dibbler						
Sminthopsis crassicaudata	Fat-tailed Dunnart						
Sminthopsis g. griseoventer	Grey-bellied Dunnart				1	1	
PERAMELIDAE	**Bandicoots & Bilby**						
Isoodon obesulus fusciventer	Southern Brown Bandicoot, Quenda						
POTOROIDAE	**Bettongs & Potoroos**						
Bettongia penicillata ogilbyi	Brush-tailed Bettong, Woylie						
MACROPODIDAE	**Kangaroos & Wallabies**						
Macropus eugenii derbianus	Tammar	1			1	1	
Macropus fuliginosus	Western Grey Kangaroo	1		1	1	1	1
Macropus irma	Western Brush Wallaby	1	1	1	1	1	1
PHALANGERIDAE	**Possums**						
Trichosurus v. vulpecula	Common Brushtail Possum					1	1
BURRAMYIDAE	**Pygmy-possum**						
Cercartetus concinnus	Western Pygmy-possum				1	1	
TARSIPEDIDAE	**Honey-possum**						
Tarsipes rostratus	Honey-possum			1	1	1	

		MON	MONN	CHN	NOW	CHE	PEN
VESPERTILIONIDAE	**Evening Bats**						
Chalinolobus gouldii	Gould's Wattled Bat	1		1			
Chalinolobus morio	Chocolate Wattled Bat	1					
Nyctophilus geoffroyi	Lesser Long-eared Bat			1			
Nyctophilus t. timoriensis	Greater Long-eared Bat						
Vespadelus regulus	Southern Forest Bat	1		1			1
MOLOSSIDAE	**Freetail Bats**						
Mormopterus species undesc	Western Freetail-bat			1			
Tadarida australis	White-striped Freetail-bat	1		1	1		
MURIDAE	**Rats & Mice**						
Hydromys chrysogaster	Water-rat					1	
Mus musculus	House Mouse			1	1	1	1
Notomys mitchelli	Mitchell's Hopping-mouse						
Pseudomys albocinereus	Ashy-grey Mouse				1		
Pseudomys occidentalis	Western Mouse				1		
Rattus fuscipes	Bush Rat				1	1	
Rattus rattus	Black Rat					1	
LEPORIDAE							
Oryctolagus cuniculus	Rabbit		1		1	1	1
CANIDAE							
Vulpes vulpes	Fox		1	1	1	1	1
FELIDAE							
Felis catus	Feral Cat		1			1	1
SUIDAE							
Sus scrofa	Pig			1			
TOTALS FOR EACH PROPERTY		7	5	12	14	15	9
FROGS							
HYLIDAE	**Tree Frogs**						
Litoria adelaidensis	Slender Tree Frog			1			
Litoria cyclorhyncha	Spotted-thighed Frog			1	1	1	
MYOBATRACHIDAE	**Ground Frogs**						
Subfamily Limnodynastinae							
Heleioporus albopunctatus	Spotted Burrowing Frog			1			1
Heleioporus eyrei	Moaning Frog						
Limnodynastes dorsalis	Western Banjo Frog			1	1		1
Neobatrachus albipes	White-footed Frog						
Neobatrachus kunapalari	Kunapalari Frog				1		
Neobatrachus pelobatoides	Humming Frog					1	
Subfamily Myobatrachinae							
Crinia georgiana	Quacking Froglet					1	
Crinia glauerti	Clicking Froglet					1	
Crinia pseudinsignifera	Granite Froglet	1			1	1	1
Myobatrachus gouldii	Turtle Frog	1			1	1	
Pseudophryne guentheri	Guenther's Toadlet						
TOTALS FOR EACH PROPERTY		2	0	4	5	6	3

		MON	MONN	CHN	NOW	CHE	PEN
REPTILES							
CHELUIDAE	**Freshwater Tortoises**						
Chelodina oblonga	Oblong Snake-necked Turtle						1
AGAMIDAE	**Dragon Lizards**						
Ctenophorus maculatus grise	Grey Spotted Dragon			1	1		
Ctenophorus ornatus	Ornate Rock Dragon						1
Pogona m. minor	Western Bearded Dragon						
GEKKONIDEA	**Geckos**						
Crenadactyllus ocellatus ocel	Ocellated Clawless Gecko				1		
Diplodactylus calcicolus	South Coast Gecko			1	1		
Strophurus spinigerus inornat	Southwest Spiny-tailed Gecko						
Underwoodisaurus milii	Barking Gecko			1	1		
Subfamily Gekkoninae							
Christinus marmoratus	Marbled Gecko			1	1		
PYGOPODIDAE	**Legless Lizards**						
Aprasia repens	Yellow-chinned Worm-Lizard						
Delma australis	Southern Delma			1			
Delma fraseri	Fraser's Delma						
Pygopus lepidopodus	Southern Scaly-foot						
SCINCIDAE	**Skinks**						
Acritoscincus trilineatum	Western Cool Skink						1
Cryptoblepharus pulcher claru	Bight Crypto				1	1	1
Ctenotus impar	Eleven-striped Ctenotus			1	1	1	
Ctenotus labillardieri	Red-legged Ctenotus						
Egernia kingii	King's Skink						
Egernia multiscutata bos	Southern Sand Skink						
Egernia napoleonis	Southern Crevice Skink						
Hemiergis i. initialis	Southwestern Earless Skink				1		
Hemiergis p. peronii	Peron's Earless Skink			1	1	1	1
Lerista distinguenda	Southwestern Four-toed Lerista			1	1	1	
Menetia greyii	Grey's Menetia			1			
Morethia obscura	Dark Morethia			1	1	1	
Tiliqua occipitalis	Western Bluetongue					1	
Tiliqua r. rugosa	Western Bobtail	1		1	1	1	1
VARANIDAE	**Goannas, Monitors**						
Varanus gouldii	Gould's Monitor					1	
Varanus rosenbergi	Rosenberg's Monitor			1	1	1	1
TYPHLOPIDAE	**Blind Snakes**						
Ramphotyphlops australis	Southern Blind Snake						
BOIDAE	**Pythons**						
Morelia spilota imbricata	Southwest Carpet Python					1	
ELAPIDAE	**Front-fanged Snakes**						
Echiopsis curta	Bardick			1			
Elapognathus coronatus	Crowned Snake						
Notechis scutatus	Western Tiger Snake			1	1	1	1
Parasuta gouldii	Gould's Snake						
Parasuta nigriceps	Black-backed Snake			1		1	
Pseudonaja a. affinis	Dugite	1		1	1	1	1

Fauna Recorded during survey work		MON	MONN	CHN	NOW	CHE	PEN
Rhinoplocephalus bicolor	Square-nosed Snake						
TOTALS FOR EACH PROPERTY		2	0	16	15	13	9
FISHES							
GALAXIIDAE							
Galaxias maculatus	Spotted Minnow					1	
Galaxias occidentalis	Western Minnow					1	
TOTALS FOR EACH PROPERTY		0	0	0	0	2	0
CRUSTACEANS							
PARASTACIDAE							
Cherax destructor	Yabby					1	
TOTALS FOR EACH PROPERTY		0	0	0	0	1	0

Survey Effort

CHE	Fauna trapping, bird minutes, opportunistic surveys,
CHN	Fauna trapping, bird minutes, opportunistic surveys,
MON	Bird minutes, opportunistic surveys
NOW	Fauna trapping, bird minutes, opportunistic surveys,
MONN	Opportunistic surveys
PEN	Fauna trapping, bird minutes, opportunistic surveys,
YAR	Bird minutes, opportunistic surveys

APPENDIX B: Species Breakdown for Each Restoration System with preference for direct seeding or seedlings.

Restoration System 1: B.media & E.falcata Tall Mallee Scrub

Plant	Seed	Seedlings
Banksia media		1
Eucalyptus pleurocarpa	1	
Eucalyptus falcata	1	
Isopogon buxifolius	1	1
Eucalyptus capitiosa	1	
Eucalyptus phaenophylla	1	
Banksia caleyi		1
Calothamnus gibbosus	1	
Dryandra nervosa		1
Hakea corymbosa	1	1
Davesia lancifolia	1	1
Eucalyptus thamnoides	1	
Eucalyptus uncinata	1	
Hakea marginata		1
Hakea pandanicarpa		1
Kunzea affinis	1	
Lepidosperma sp.		1
Melaleuca bracteosa	1	
Schenous sp.		1
Beaufortia schaueri	1	
Calothamnus gracilis	1	
Desmocladus sp.		1
Gahnia ancistrophylla		1
Gastrolobium spinosum	1	
Hakea commutata		1
Kunzea recurva	1	
Melaleuca scabra	1	
Taxandria spathulata	1	
Allocasuarina thyoides	1	
Baeckea sp.	1	
Callitris roeii		1
Gompholobium confertum		1
Gompholobium scabra		1

Plant	Seed	Seedlings
Hakea prostrata		1
Isopogon trilobus		1
Lambertia inermis		1
Melaleuca carrii	1	
Santalum accuminatum	1	
Acacia littorea	1	
Acacia mimica var. mimica	1	
Agonis spathulata	1	
Beaufortia sp.	1	
Boronia octandra		1
Bossiaea spinescens		1
Callitris sp.		1
Caustis dioica		1
Davesia incrassata	1	1
Davesia sp.	1	1
Epacrid sp.		1
Exocarpos sparteus	1	1
Grevillea dolichopoda		1
Hakea laurina		1
Hakea trifurcata		1
Isopogon seminuda		1
Leptospermum sp.	1	
Leucopogon sp.		1
Lysinema sp.		1
Melaleuca hamata	1	
Melaleuca pentagona	1	
Melaleuca tuberculata	1	
Neurachne allopecuroidea		1
Petrophile seminuda		1
Rinzia sp.	1	1
Tetrapora verrucosa	1	1
Xanthorrhea sp.		1

Species to Direct Seed	**29**
Species to Hand Plant	**35**

Restoration System 2: YATE (Eucalyptus occidentalis) Swamp Woodland

Plant	Seed	Seedlings
Eucalyptus occidentalis	1	1
Acacia cupularis	1	
Acacia saligna	1	
Acacia microbotrya	1	
Banksia media		1
Calistemon phoenecious	1	
Eucalyptus uncinata	1	
Melaleuca accuminata	1	
Melaleuca hamata	1	
Melaleuca hamulosa	1	
Acacia assimilis	1	
Acacia sphacelata	1	
Calothamnus gibbosus	1	
Eucalyptus thamnoides	1	
Eucalyptus xanthonema	1	
Exocarpos aphyllus	1	1
Gastrolobium parviflorum	1	
Grevillea dolichopoda		1
Grevillea sp.		1
Astroloma sp.		1
Desmocladus sp.		1
Dodonaea amblyophylla	1	
Dodonaea sp.	1	
Dryandra tenuifolia		1
Eucalyptus melanophytra		1
Lepidosperma sp.1		1
Lepidosperma sp.2		1
Lomandra caesia		1
Lomandra sp.		1
Neurachne sp.		1
Santalum accuminatum	1	1

Species to Direct Seed	**19**
Species to Hand Plant	**15**

Restoration System 3: Banksia media, Eucalyptus pleurocarpa and Lamberitia inermis

Plant	Seed	Seedlings	Plant	Seed	Seedlings
Banksia media		1	Caustis dioica		1
Eucalyptus pleurocarpa	1		Chamelaucium ciliatum		1
Eucalyptus falcata	1		Davesia incrassata	1	1
Isopogon buxifolius	1	1	Davesia sp.	1	1
Beaufortia micrantha	1		Epacrid sp.		1
Dryandra cirsioides		1	Exocarpos sparteus	1	1
Eucalyptus capitiosa	1		Grevillea dolichopoda		1
Eucalyptus phaenophylla	1		Hakea laurina		1
Banksia caleyi		1	Hakea trifurcata		1
Calothamnus gibbosus	1		Isopogon seminuda		1
Dryandra nervosa		1	Leucopogon sp.		1
Hakea corymbosa	1	1	Lysinema sp.		1
Melaleuca spathulata	1		Melaleuca hamata	1	
Melaleuca violacea	1		Melaleuca pentagona	1	
Davesia lancifolia	1	1	Melaleuca sp.	1	
Eucalyptus thamnoides	1		Melaleuca tuberculata	1	
Eucalyptus uncinata	1		Neurachne allopecuroidea		1
Hakea marginata		1	Petrophile seminuda		1
Hakea pandanicarpa		1	Petrophile sp.		1
Kunzea affinis	1		Rinzia sp.	1	1
Lepidosperma sp.		1	Tetrapora verrucosa	1	1
Melaleuca bracteosa	1		Xanthorrhea sp.		1
Schenous sp.		1	Acacia bidentata	1	
Beaufortia schaueri	1		Allocasuarina humilis	1	
Calothamnus gracilis	1		Anigozanthus rufa	1	1
Gahnia ancistrophylla		1	Baeckea preissiana	1	1
Gastrolobium spinosum	1		Banksia nutans		1
Kunzea recurva	1		Brachysema sp.		1
Melaleuca scabra	1		Conospermum coerulescens		1
Taxandria spathulata	1		Conothamnus aureus		1
Allocasuarina thyoides	1		Dampiera sp.		1
Baeckea sp.	1		Davesia emarginata	1	1
Callitris roeii		1	Desmocladus aspa		1
Gompholobium confertum		1	Dryandra sessilis		1
Gompholobium scabra		1	Franklandia fascifolia		1
Hakea prostrata		1	Gastrolobium latifolium		1
Isopogon trilobus		1	Lechenaultia tubiflora		1
Lambertia inermis		1	Lisonema capitatum		1
Melaleuca carrii	1		Loxocaria sp.		1
Santalum accuminatum	1		Melaleuca societalis	1	
Acacia littorea	1		Mesomelina stygia		1
Acacia mimica var. mimica	1		Nutsya floribunda	1	1
Acrotriche ramiflora		1	Petrophile teretifolia		1
Agonis spathulata	1				
Boronia octandra		1	Species to Direct Seed	44	
Bossiaea spinescens		1	Species to Hand Plant	58	
Callitris sp.		1			

Restoration System 4: B. media, E. falcata, and Dryandra circioides Mallee Scrub

Plant	Seed	Seedlings
Banksia media		1
Eucalyptus pleurocarpa	1	
Eucalyptus falcata	1	
Isopogon buxifolius	1	1
Beaufortia micrantha	1	
Dryandra cirsioides		1
Eucalyptus capitiosa	1	
Eucalyptus phaenophylla	1	
Banksia caleyi		1
Calothamnus gibbosus	1	
Dryandra nervosa		1
Hakea corymbosa	1	1
Melaleuca spathulata	1	
Melaleuca violacea	1	
Davesia lancifolia	1	1
Eucalyptus thamnoides	1	
Eucalyptus uncinata	1	
Hakea marginata		1
Hakea pandanicarpa		1
Kunzea affinis	1	
Lepidosperma sp.		1
Melaleuca bracteosa	1	
Schenous sp.		1
Beaufortia schaueri	1	
Calothamnus gracilis	1	
Desmocladus sp.		1
Gahnia ancistrophylla		1
Gastrolobium spinosum	1	
Hakea commutata		1
Kunzea recurva	1	
Melaleuca scabra	1	
Taxandria spathulata	1	
Allocasuarina thyoides	1	
Baeckea sp.	1	
Callitris roeii		1
Gompholobium confertum		1
Gompholobium scabra		1
Hakea prostrata		1
Isopogon trilobus		1
Lambertia inermis		1
Melaleuca carrii	1	
Santalum accuminatum	1	

Plant	Seed	Seedlings
Acacia littorea	1	
Acacia mimica var. mimica	1	
Acrotriche ramiflora		1
Agonis spathulata	1	
Beaufortia sp.	1	
Boronia octandra		1
Bossiaea spinescens		1
Callitris sp.		1
Caustis dioica		1
Chamelaucium ciliatum		1
Davesia incrassata	1	1
Davesia sp.	1	1
Epacrid sp.		1
Exocarpos sparteus	1	1
Grevillea dolichopoda		1
Hakea laurina		1
Hakea trifurcata		1
Isopogon seminuda		1
Leptospermum sp.	1	
Leucopogon sp.		1
Lysinema sp.		1
Melaleuca hamata	1	
Melaleuca pentagona	1	
Melaleuca sp.	1	
Melaleuca spathulata x pent	1	
Melaleuca tuberculata	1	
Neurachne allopecuroidea		1
Petrophile seminuda		1
Petrophile sp.		1
Rinzia sp.	1	1
Tetrapora verrucosa	1	1
Xanthorrhea sp.		1

Species to Direct Seed	**40**
Species to Hand Plant	**42**

Restoration System 5: Eucalyptus vergrandis, E. annulata, & E. conglobata

Plant	Seed	Seedlings	Plant	Seed	Seedlings
Eucalyptus vergrandis	1		Cassytha sp.		1
Acacia glaucoptera	1		Chamelaucium ciliatum		1
Coopernookia polygalacea	1	1	Conospermum sp.		1
Davesia sp.	1	1	Dianella sp.	1	1
Grevillea pectinata		1	Dodonaea sp.	1	
Lepidosperma sp.1		1	Dryandra tenuifolia		1
Lepidosperma sp.2		1	Eucalyptus flocktoniae	1	
Acacia harveyii	1		Eucalyptus uncinata	1	
Acacia lasiocarpa	1		Eucalyptus xanthonema	1	
Eucalyptus annulata	1		Exocarpos aphyllus	1	1
Eucalyptus conglobata	1		Gastrolobium tetragonophy	1	1
Eucalyptus platypus	1		Ghania ancistrophylla		1
Exocarpos sparteus	1	1	Ghania frifida		1
Gastrolobium parviflorum	1		Grevillea oligantha		1
Melaleuca carrii	1		Grevillia pectinata		1
Melaleuca cucculata	1		Guichenotia sp.	1	1
Melaleuca hamata	1		Hakea laurina		1
Melaleuca scabra	1		Hemeginia sp.		1
Melaleuca spathulata	1		Leptospermum maxwellii	1	
Ozothamnus lepidophylla	1		Leucopogon gibbosus		1
Pimelia sp.		1	Melaleuca calycina	1	
Acacia cupularis	1		Melaleuca haplantha	1	
Acacia cyclops	1		Melaleuca lateralis	1	
Acacia spheracarpa	1		Melaleuca lateriflora	1	
Acrotriche sp.		1	Melaleuca undulata	1	
Alygoine sp.	1		Melaleuca violacea	1	
Astroloma sp.		1	Microcorys glabra		1
Austrostipa sp.	1		Opercularia sp.		1
Baeckea sp.		1	Ozothamnus sp.		1
Billedaria sp.	1	1	Phebaleum reversifolia	1	1
Boronia sp.	1	1	Santalum murrayanum	1	1
Calothamnus gibbosus	1				
			Species to Direct Seed	**42**	
			Species to Hand Plant	**32**	

Restoration System 6: Eucalyptus platypus / Eucalyptus vessiculosa Woodlands

Plant	Seed	Seedlings
Melaleuca accuminata	1	
Eucalyptus annulata	1	
Acacia cyclops	1	
Acacia harveyii	1	
Eucalyptus flocktoniae	1	
Eucalyptus platypus	1	
Eucalyptus vesiculosa	1	
Eucalyptus xanthonema	1	
Melaleuca cucculata	1	
Acacia glaucoptera	1	
Acacia trulliformis	1	
Alygoine sp.		1
Austrodanthonia sp.	1	
Calothamnus quadrifidis	1	
Dodonaea sp.	1	
Eucalyptus conglobata	1	
Gastrolobium sp.	1	
Hakea strumosa		1
Melaleuca bracteosa	1	
Melaleuca calycina	1	
Melaleuca hamata	1	
Melaleuca pentagona	1	
Melaleuca scabra	1	
Rhagodia sp.	1	1
Santalum accuminatum	1	1

Species to Direct Seed	**23**
Species to Hand Plant	**4**

Restoration System 7: B.media & E.pluricaulis Mallee Scrub

Plant	Seed	Seedlings	Plant	Seed	Seedlings
Eucalyptus pleurocarpa	1		Boronia sp.		1
Banksia media		1	Calitris glaucophylla		1
Eucalyptus uncinata	1		Callitris roeii		1
Isopogon buxifolius	1	1	Darwinia sp.		1
Melaleuca scabra	1		Davesia sp.	1	1
Melaleuca spathulata	1		Dryandra nervosa		1
Banksia caleyi		1	Epacrid sp.		1
Eucalyptus phaenophylla	1		Eucalyptus conglobata	1	
Eucalyptus pluricaulis	1		Eucalyptus falcata	1	
Melaleuca violacea	1		Eucalyptus vergrandis	1	
Beaufortia schaueri	1		Eucalyptus xanthonema	1	
Eucalyptus thamnoides	1		Exocarpos aphyllus	1	1
Grevillea oligantha		1	Gahnia ancistrophylla		1
Hakea laurina	1	1	Gastrolobium spinosum	1	
Lepidosperma sp.	1		Hakea corymbosa		1
Melaleuca bracteosa	1		Hakea marginata		1
Baeckea sp.	1		Hakea pandanicarpa		1
Beaufortia micrantha	1		Hibbertia recurvifolia		1
Calothamnus gibbosus	1		Leucopogon reversifolia		1
Chamelaucium ciliatum		1	Melaleuca hamata	1	
Davesia lancifolia	1	1	Melaleuca haplantha	1	
Dryandra tenuifolia		1	Patersonia sp.	1	1
Eucalyptus capitiosa	1		Persoonia longifolia	1	1
Kunzea affinis	1		Restionacea sp.		1
Kunzea recurva	1		Santalum murrayanum	1	
Melaleuca araucarioides	1		Schenous sp.		1
Acacia sphacelata	1		Verticordia fastigiata		1
Acrotriche sp.		1			
Astatea sp.		1	Species to Direct Seed	**34**	
			Species to Hand Plant	**29**	

APPENDIX C: Soil Pit Photos for Monjebup North Ecological Restoration Plan Soil Assessment

Pit 1

Pit 2

Pit 3

Pit 4

Pit 5

Pit 6

Pit 7

Pit 8

Pit 9

Pit 10

Pit 11

Pit 12

Pit 13

Pit 14

Pit 15

Pit 16

Pit 17

Pit 18

Pit 19

Pit 20

Pit 21

Pit 22

Pit 23

Pit 24

Pit 25

Pit 26

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Pit 103

Pit 104

Pit 105

Pit 106

Pit 107

Pit 108

Pit 109

Pit 110

Pit 111

Pit 112

Pit 113

Pit 114

Pit 115

Pit 116

Pit 117

Pit 118