Identifying cost-effective reforestation approaches for biodiversity conservation and carbon sequestration in southern Australia

Final Report to the Australian Flora Foundation

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Project Summary

Our aim was to determine the reforestation approach that maximises the native biodiversity found in Mallee bushland regrowth in South Australia, while simultaneously maximising carbon sequestration. We have implemented a long-term reforestation experiment testing six approaches (3 biodiversity treatments: 1. monoculture, 2. low diversity, 3. high diversity; and 2 planting densities: 1. high and 2. low) for reforesting deforested land into secondary shrubland and woodland complexes at Monarto Zoo, South Australia. To assess goals, we are continuing to monitor key taxa (vegetation, invertebrates, small mammals, reptiles) and carbon pools prior to reforestation and throughout the regeneration process. Our study is unique in its experimental assessment of temperate Australian reforestation for biodiversity conservation and in the collection of baseline data. This study will eventually result in guidelines for woodland/shrubland reforestation as an economically viable land use for landholders.

Background

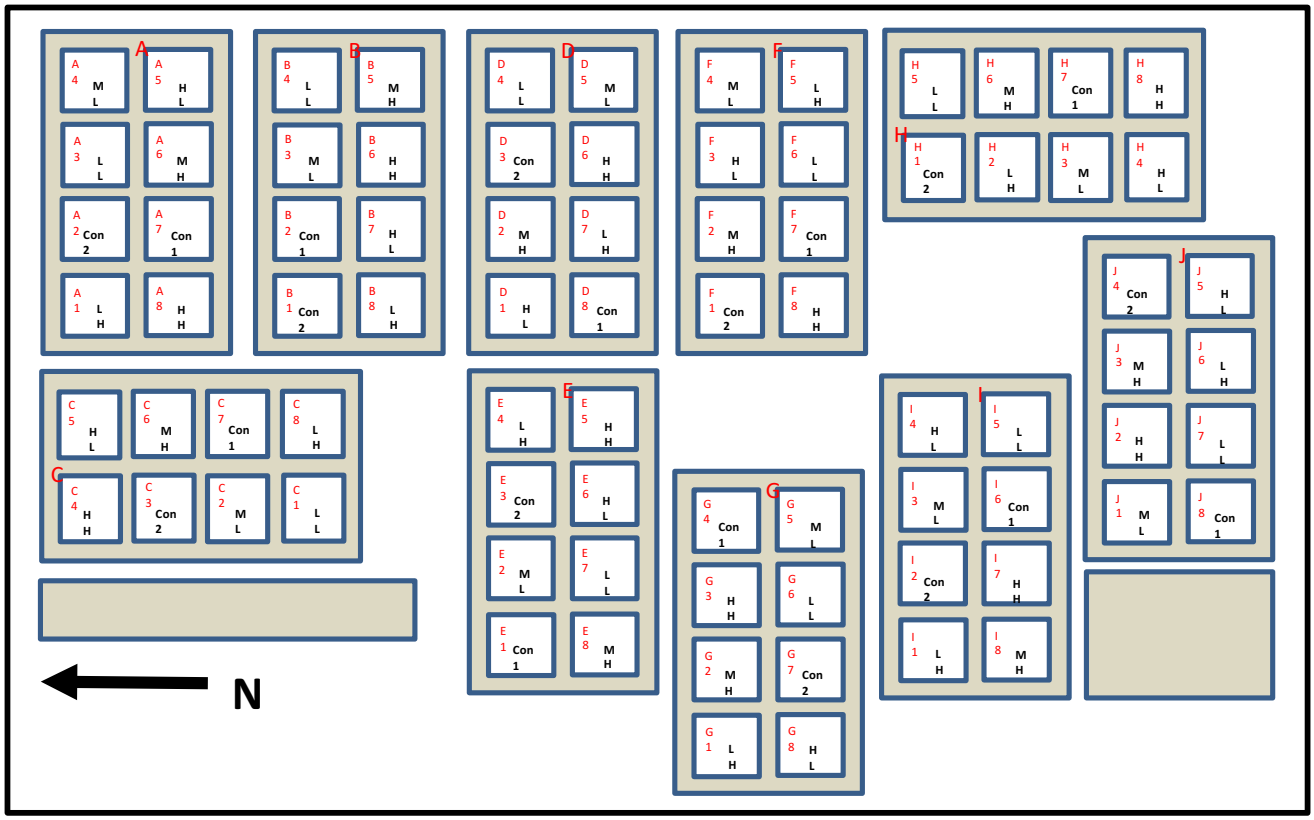
This Australian Linkage Project, with co-funding from the Australian Flora Foundation, the South Australia Department of Environment, Water and Natural Resources and Zoos SA began in 2013 at Monarto Zoo, South Australia. Staff of Zoos SA were mostly responsible for the day-to-day monitoring, propagation, planting, watering and general care of the site.

Site

The project site is located in a single soil type of approximately 20 ha of previously cleared agricultural land at Monarto Zoological Park, South Australia.

Experimental Design

The experiment comprises 10 **blocks**, and each block comprises 8 **plots**: 6 reforestation plots plus two control plots totalling 80 plots across the site.



Each plot consists of a single 25 × 25 m square surrounded by a 5 m buffer zone (10 m total between plots). Buffer zones were not planted, but are managed throughout the experiment to keep grasses under control through slashing. Prior to any activity the site was slashed and sprayed to control weeds.

Biodiversity-density treatments

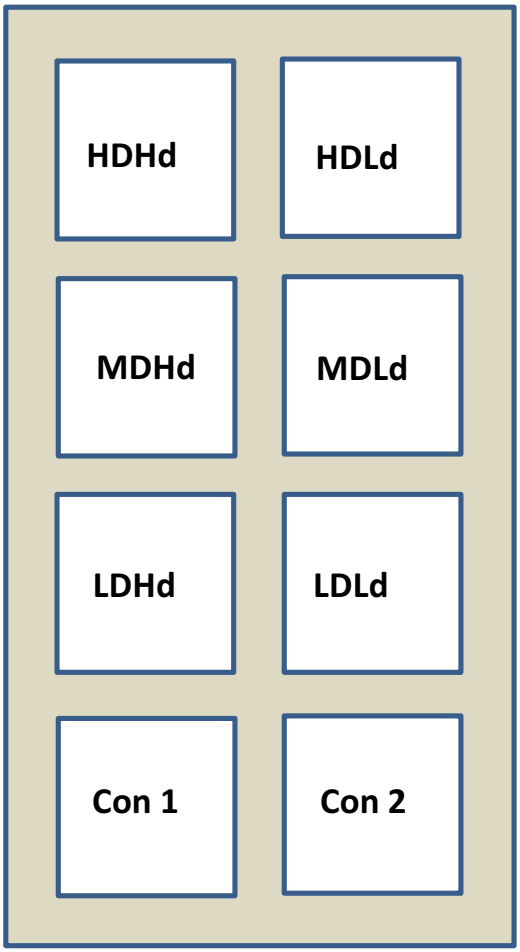
The two principal manipulations were: (1) a three-level biodiversity and (2) a two-level planting density treatment. Each plot was assigned randomly one of 6 replanting treatments or one of 2 controls so that each block has a single, randomly ordered representative of each treatment. Species were chosen on the basis of

availability of propagating material (seed), germination success and seedling survival in both the nursery and the field. A series of harvest plots (for carbon sequestration measurements) have also been established in areas adjacent to the experimental plots.

The three-level biodiversity treatment included: (1) **native tree monoculture (low-diversity LD)**: *Eucalyptus porosa* Mallee Box; (2) **low-diversity mixed (medium-diversity MD) culture** (3 species): *Eucalyptus porosa*, *Acacia rhigiophylla* dagger-leaf wattle, *Enchylaena tomentosa* ruby saltbush; (3) **high-diversity (HD) mixed culture** (10 species): *Eucalyptus porosa*, *Eucalyptus leucoxylon* South Australian blue gum, *Melaleuca acuminata* Mallee honey myrtle, *Acacia rhigiophylla*, *Acacia brachybotrya* grey mulga bush, *Pomaderris paniculosa* pomaderris, *Enchylaena tomentosa*, *Rhagodia crassifolia* fleshy saltbush, *Prostanthera aspalathoides* scarlet mintbush, *Maireana brevifolia* short-leaf bluebush. Due to poor survival of *P. paniculosa*, we replaced its dead seedlings with *Senna artemisioides filifolia* in 2015.

Each of the three biodiversity treatments were planted at two different densities: (1) high-density (**Hd**) plantings: tubestock spaced at 1.5 m apart, and (2) low-density (**Ld**) plantings: tubestock spaced 3 m apart.

The two control plots included in each block comprise: (1) **grass management**: mow twice per year and (2) **no manipulation**.



HD = high diversity

MD = medium diversity

LD = low diversity

Hd = high density

Ld = low density

Con 1 = control 1 (grass management control)

Con 2 = control 2 (no management)

We created a temporary grid structure to provide a standard reliable measuring system for planting, with holes for each tubestock drilled at each intersecting joint. We assigned each plant a code according to the location on the grid system to enable ease of monitoring, recording of plant death, and for growth measurement. In 2013 there was some *Enchylaena tomentosa* deaths that occurred during the months immediately after planting. We replaced these plants in June-August 2014.

Due to underplanting in 2013, we added plants to increase plot size in June 2014. We added 72 plants per high-density treatment plots and 20 plants per low-density treatment plots. Plant deaths (see Results below) and additional increasing plot areas led to additional plants planted in June 2015.

Monitoring

Soil carbon

We did random soil coring and geophysical surveys (ground-penetrating radar) to determine soil composition and depth, respectively prior to the onset of planting. These results are still being analysed, but will not be meaningful until at least 5-10 years post-planting so that they provide a reasonable reference point for the long-term effects of soil on carbon characteristics of the soil.

Vascular and non-vascular plants

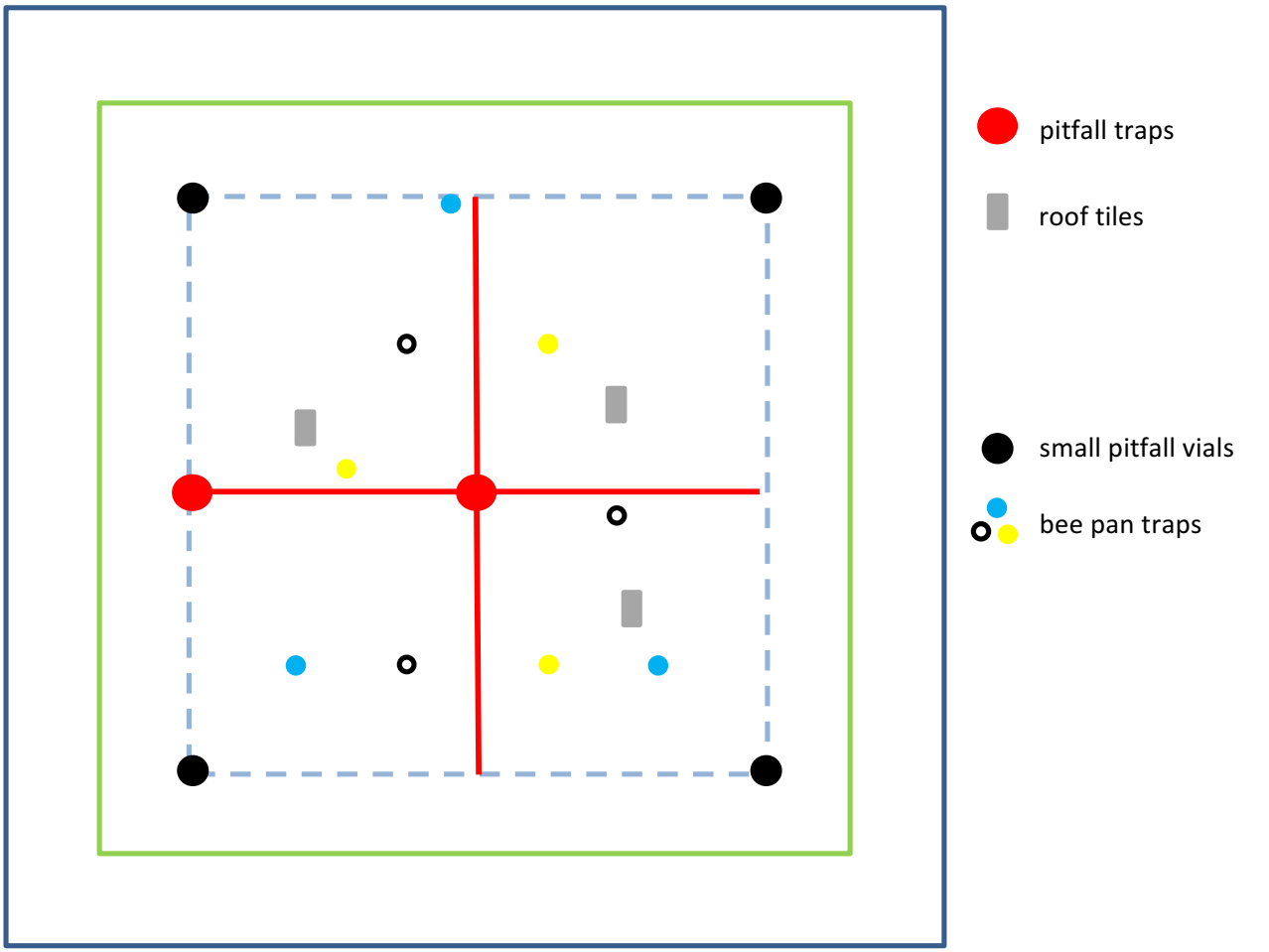
Plant surveys before and after first planting followed a nested vegetation sampling method. Prior to planting, we mapped out the experimental plots and set up permanent plant surveying subplots using pin markers with each location recorded using GPS. In each experimental plot we established the following nested quadrats: one 15 × 15 m quadrat for sampling trees > 10 cm diameter at breast height (dbh) and two 10 × 5 m plots for sampling woody species < 10 cm dbh. We positioned the quadrats for sampling woody species in the centre of each 25 × 25 m experimental reforestation plot, allowing for a 10 m buffer from the plot edge and the sampled area.

We used the step-point method to sample herbs and non-vascular plants across the site. We sampled four transect lines 300 m each running diagonally through the site, with 200 sampling 'points' along each line and 1.5 m between each sampling point. At each point all plant species within a hand span. Given the former history of the site, the vegetation was predominantly pasture grasses and agricultural pest plants such as horehound; however, there were many native plant species recorded including *Austrostipa* and *Rytidosperma* sp., *Enchylaena tomentosa*, and *Dodonaea viscosa*.

In each plot we recorded the identity and abundance of all plant species in Year 2. We labelled all woody species for ease of future sampling throughout the study. For pre-experiment surveys, we established 10 nested plots in nearby forest fragments at least 100 m from the forest edge. These plots will provide the necessary data for comparison with developing experimental reforestation plots.

Bees

We used standard pan trap and netting techniques to survey bees living in the cleared paddock before planting treatments and in plots after planting. To ensure comparability among plots, we established permanent sampling sites within the centre of each of the treatment plots within all 8 replicate blocks (80 in total). Pan traps are made of blue, white and yellow plastic bowls filled with water and no-scent detergent. These traps attract bees that fly into the water and drown. Individual sampling sites consisted of nine bowls (three of each colour) placed in a triangle around the centre point, each spaced 2.5 m apart.



We set the bee traps for five 24-hour periods during the year. Ten sampling sites of the same design were located within the nearby forest patches. Five of these are located near the forest edge, and the remaining five are placed more than 100 m from the forest edge in the interior of the patch. We also net-trapped bees by walking for 30 min intervals throughout each experimental plot, netting any bees seen in the morning and late afternoon.

Other invertebrates

We sampled other invertebrates using pitfall and flight intercept traps. We used the same spatial arrangement of trap locations as for the bees to maximise efficiency of the field surveys. We placed a set of four pitfall traps 10 m apart at the centre of each treatment plot, thereby ensuring that there is at least 50 m between sets of replicates in different plots. We set traps one 5 day period once a year. We also ran ten sampling sites of the same design within adjacent forest patches, following the same spatial arrangement as for the bees. Invertebrate processing and collation is still being done.

Reptiles

We used standard roofing tiles laid out at 3 per plot across the entire site set for small lizards (e.g., mainly scincids) per plot measured in October. We marked and released captured lizards, recording species identity and snout-vent length as an index of size. We did no permanent notching or marking. We repeated surveys and pitfall traps in adjacent remnants for comparison as described for other taxa.

Mammals

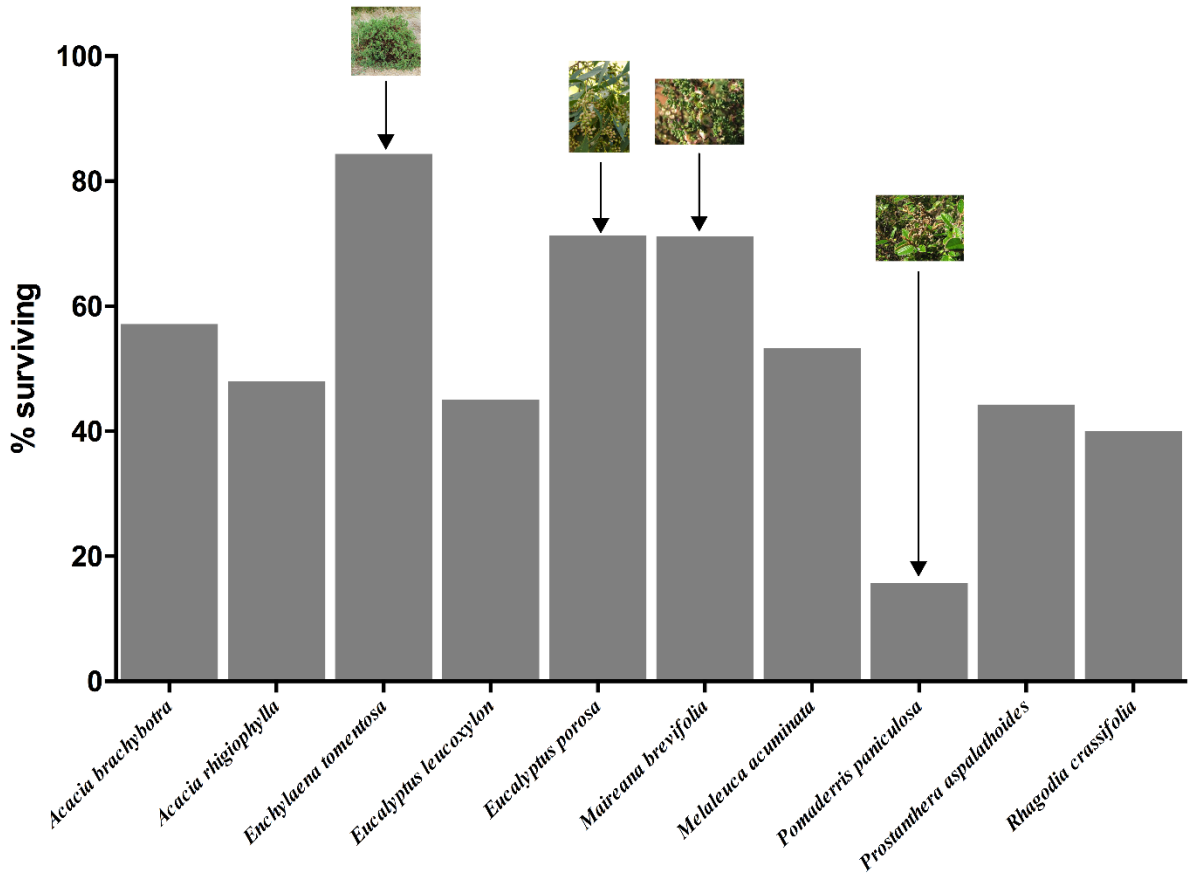
Although mammals were not the focus of our project, we recorded any captures during surveys (e.g., in the pitfalls.

Results to date

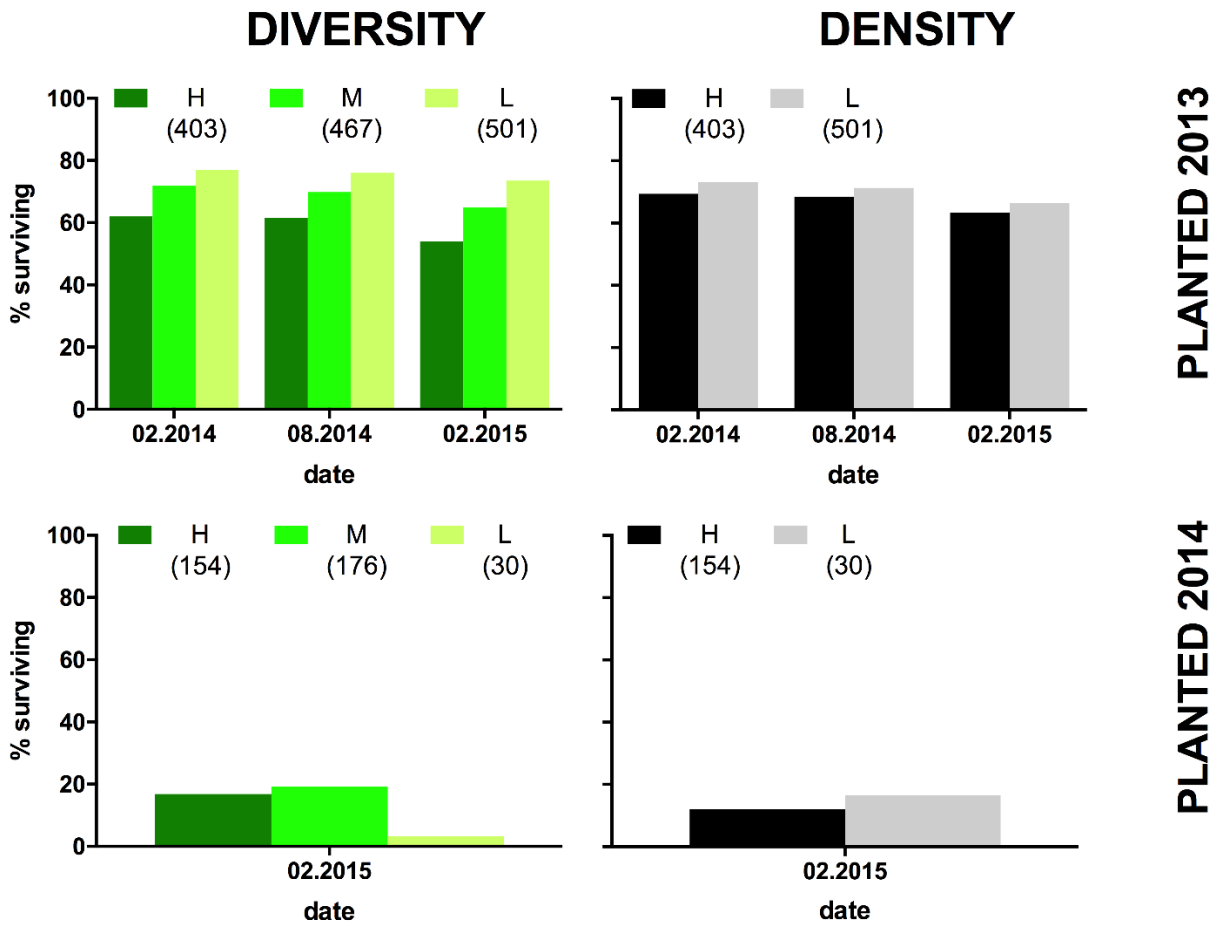
We planted a total of 7800 individual plants over three years of planting, with 602 (2014) and 3280 (2015) individuals replanted.

Monitoring results are still highly preliminary at this stage because of the slow growth rate of the species planted, continuing identification of invertebrates collected, and the long lag time from multiple plantings. Preliminary results appear to indicate:

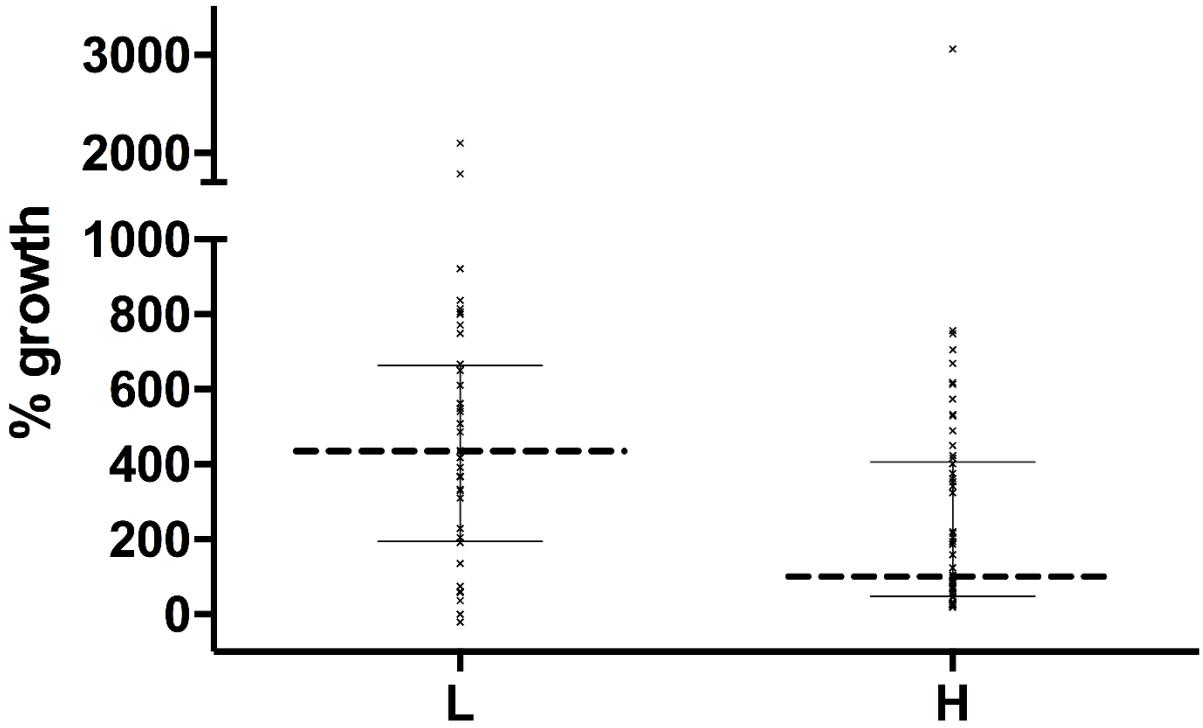
- *Pomaderris paniculosa* had the lowest survival
- We recorded highest survival in *Enchylaena tomentosa*, *Eucalyptus porosa*, and *Maireana brevifolia*



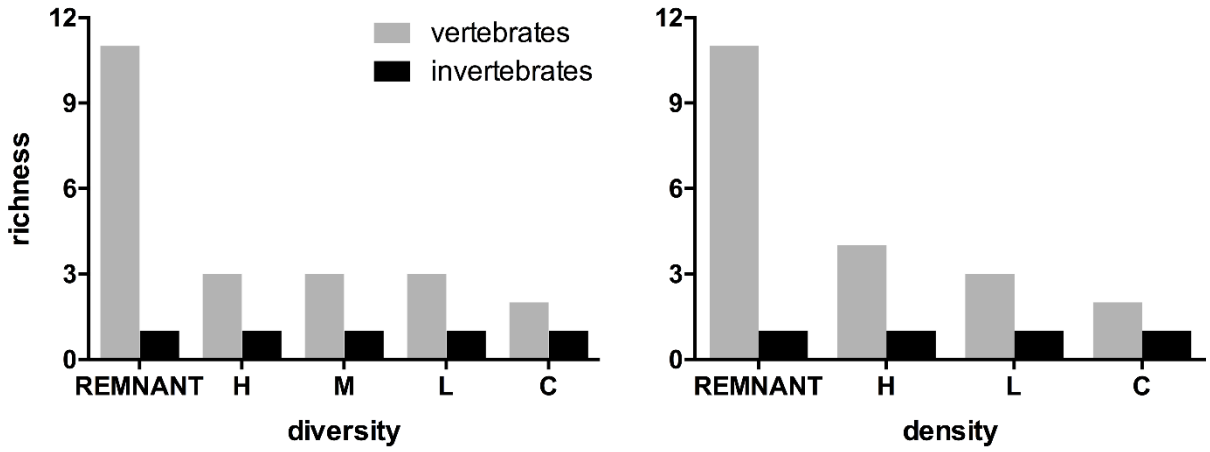
- Seedling survival was higher in the low-diversity plots, mainly due to the high survival of *E. porosa* in the monoculture treatments
- There was a consistently lower survival in the high-density plots, but the difference was small



- Growth rates (% height or % radius increase) was also highest in the low-density plots



- Fauna monitoring is not yet complete, but to date the only suggested influence of the treatments was slightly higher vertebrate densities in the high-density plots, likely due to relatively more continuous plant cover



Future plans

Given the slow growth rates of Mallee-type vegetation, we expect that monitoring will need to continue for a minimum of 15-20 years before the full extent of the ideal planting scenarios are known. We are currently seeking additional funding for ongoing monitoring at a reduced frequency (perhaps biannually) so we can build a long-term database of vegetation growth and biodiversity use.