Title – Evaluating restoration outcomes: trial of a community-based monitoring protocol

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Summary  Restoration planting is undertaken widely in rural landscapes to promote more sustainable land-use, such as reforesting agricultural land, and to enhance nature conservation. Land managers and community groups have a key role in delivering these actions and can also contribute to monitoring the outcomes. Here, we describe a monitoring protocol developed to assist practitioners to assess the survival of plant species in restoration plantings, and report results of a trial of the protocol from 123 monitored plots at 62 sites across Victoria. On average, 61% of plants per site (all species combined) survived and 77% of the species planted persisted after the first summer post-planting. Rates of survival varied considerably among plant species, with differences in outcomes evident across bioregions. Overall, the survival of plantings (all species combined) was greater at sites with higher mean annual rainfall and where plants were protected by guards. Widespread adoption of monitoring will assist project managers to better understand how plants survive and grow, and to adaptively manage revegetation programs under a changing climate. A coordinated monitoring effort will require resources for on-ground monitoring, as well as an online database for data storage, collation, analysis and reporting.

Introduction
Planting of local native trees, shrubs and understory species is a key component of habitat restoration and the recovery of native floral and faunal communities in regions where loss of native vegetation has occurred, typically as a result of extensive land clearing for agriculture and urban development (Collard et al. 2020). In rural landscapes, restoration through revegetation can contribute to more sustainable land-use by reducing soil loss, protecting water quality, capturing and storing carbon (Freudenberger 2018), and providing social benefits and other ecosystem services.

Survival and growth of plants in the early post-planting period are key outcomes to measure the short-term success of restoration. Monitoring and documenting such outcomes is an important step
in assessing the success of planting practices and making improvements over time (Jellinek et al. 2020b). Land managers and community groups who carry out on-ground planting activities can play a vital role in collecting such monitoring information, if they have the resources to do so (Hobbs 2018).

Here, we report on a project that engaged community groups and land managers in a trial monitoring program of restoration planting sites in south-eastern Australia. We developed a simple monitoring protocol that agencies and community groups could use to collect information in a standardised way to assess planting outcomes (Jellinek et al. 2020a). The aim of the study was: (a) to assess the outcomes, measured by the survival of planted trees, shrubs and understory plants; and (b) to determine factors that affect variation in survival among species and geographic regions.

**Methods**

We invited revegetation practitioners across Victoria, Australia, including Catchment Management Authorities and Landcare groups, to participate in a trial. Participants initially used the protocol (Jellinek et al. 2020a) during or up to one month after planting (June to September 2019), to collect information about planting sites, land-use history, site preparation and plantings; and then again after the first summer (March to April 2020) to assess survival of plants. Monitoring plots (50 m x 4 m) were established at random locations in each planting site, marked by GPS and star pickets. Two to three plots were established per 1 ha planting site. The observer recorded the number of each native species (to species level) that was planted and alive within the plot area. They also recorded whether plants were protected by plant guards, the presence/absence of grazing (by rabbits, deer or macropods), and an estimate (% cover) of weed species within the plot (see Fig. S1 for full monitoring methods). All sites were in farming landscapes, initially dominated by pasture grasses, and fenced to exclude livestock. Tubestock (hiko cells – 43mm wide and 100mm deep or forestry tubes – 50mm wide and 150mm deep) was the container size used in all revegetation locations.

The overall proportion of plants surviving (all species combined) and the proportion of species persisting after the first summer were each calculated at the site level (by calculating mean values per plot). Similarly, the survival after the first summer of plants representing different growth forms (i.e. tree stratum, shrub stratum or ground stratum species) was calculated for each site. These data were compared across five biogeographic regions in Victoria (i.e. Interim Biogeographic Regions Australia; IBRA). IBRA bioregions were chosen to compare planting outcomes because they are geographically distinct areas that have a common climate, geology, landform, native vegetation and species information. We used analysis of variance (ANOVA) to test for differences in proportional...
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survival between bioregions, and between growth forms. A least-squares means function was used, together with a Tukey test to show differences in survival between categories (bioregions, growth form), undertaken in R (version 4.0.2).

Survival of plants after the first summer, for the 16 most commonly planted species across the five bioregions, was also calculated for each site and mean values plotted. To examine factors influencing the survival of plants (all species combined), we used a generalised linear mixed model (GLMM) with predictor variables including mean annual rainfall, maximum mean temperature for the hottest month, presence/absence of guards, presence/absence of grazing herbivores, soil type (see Table S1) and weed cover. The response variable, the mean proportion of plants per plot that survived the first summer (i.e. plants alive after summer/total plants planted), was modelled using a beta distribution and a logit link function using the glmmTMB package in R. Site was included as a random effect to account for the clustering of plots within sites. Bioregion was excluded as it was strongly correlated with climate variables and soil type. Mean annual rainfall (336 – 1066mm per annum at study sites) and maximum mean annual temperature for the hottest month (23 to 32 degrees Celsius) for each site were obtained from the Bureau of Meteorology (www.bom.gov.au). Soil profile data were obtained from the Victorian Government data portal (www.data.vic.gov.au).

Results

In total, 62 sites (containing 123 plots) were monitored across five bioregions, including South-eastern Highlands (9 sites, 15 plots), Victorian Volcanic Plains (6 sites, 12 plots), South-east Coastal Plain (34 sites, 58 plots), Victorian Midlands (10 sites, 30 plots) and Murray Darling Depression (3 sites, 8 plots). Participants in the trial represented 16 groups, including government land managers and community Landcare groups.

Between planting and the end of the first summer, a mean of 61% (range = 58 - 64%; SE = 0.03) of plants per site (all species combined) survived. Similarly, a mean of 77% (range = 74 - 80%, SE = 0.03) of the number of species planted per site survived their first summer. There was no significant difference in the survival of plants of different growth form types (degrees of freedom = 2, F = 2.31, \( p = 0.103 \); ground stratum = 57%, shrub stratum = 51%, tree stratum = 64% survival).

When comparing bioregions (Fig. 1a, b), planting density and species richness during winter and early spring plantings were highest in the South-eastern Highlands (SEH) and the Victorian Volcanic Plains (VVP). There was a significant difference between bioregions in the proportion of plants (all species combined) that survived the first summer (degrees of freedom = 4, F = 6.91, \( p < 0.001 \)). The proportional survival per site was lower in the Victorian Volcanic Plains and the Victorian Midlands.
compared to the Murray Darling Depression, the South-eastern Highlands and the South-east Coastal Plain (Fig. 1b). Similarly, there was a significant difference between bioregions in the proportional decline in species richness after the first summer (degrees of freedom = 4, F = 10.53, $p < 0.001$), with a greater decline in the Victorian Volcanic Plains than in all other Bioregions (Fig. 1a).

For the 16 most commonly planted species, the proportion of plants per site surviving after the first summer differed substantially (Fig. 1c). Of these commonly planted species, Swamp Paperbark (*Melaleuca ericifolia*), Hop Goodenia (*Goodenia ovata*), wattles (*Acacia* spp.), Manna Gum (*Eucalyptus viminalis*) and Swamp Gum (*E. ovata*) had the highest proportional survival (68% to 84% per site) over the monitoring period. In comparison, Tree Everlasting (*Ozothamnus ferrugineus*), Woolly Teatree (*Leptospermum lanigerum*), Sweet Bursaria (*Bursaria spinosa*) and Drooping Sheoak (*Allocasuarina verticillata*) had relatively lower survival (37% to 52% per site) after the first summer (Fig. 1c).

A model of the factors influencing the proportional survival of plants (all species combined) after the first summer found that mean annual rainfall ($p = 0.020$) and protection by guards ($p = 0.030$) had a significant effect (see Table S2). A greater proportion of plants survived at sites with higher rainfall and if plants were guarded. Soil type, maximum mean temperature for the hottest month, weed cover and the presence of grazing by European Rabbit (*Oryctolagus cuniculus*), deer (*Cervus* spp., *Axis* spp. and *Dama* spp.) or macropods (*Macropus* spp. and *Wallabia* spp.) did not have a significant influence on the proportion of plants surviving in this trial.
Management Implications

The simple protocol we trialled in this project proved successful in collecting information that can demonstrate the relative success of plantings, and variation in survival in relation to environmental and management factors. Although there were relatively few monitoring sites in each bioregion, comparison across bioregions provided useful insights. Feedback from participants suggested that the methods were relatively easy to use and understand.

On average, survival of plants after the first summer (61%, all species combined), was relatively low compared to other recent studies in south-eastern Australia (69 - 94%) (Jellinek et al. 2020b), but higher than some studies in south-western Australia (53%) (Hallett et al. 2014). However, some experimental plantings in south-western Australia show high survival (91 - 95%) (Perring et al. 2012), suggesting plant survival can be highly variable between or even within planting locations.

Average annual rainfall is substantially higher in the South-eastern Highlands, which likely explains why this region was planted more densely than other bioregions and was among the regions with higher proportional survival of individual plants and species richness after the first summer.

Protection of plants by tree guards is known to reduce the impact of herbivory, as well as potentially create a more stable microclimate for plant species (Bennett et al. 2020). The Victorian Volcanic Plains had lower survival than other bioregions potentially as a result of proportionally lower rates of plant guarding and higher rates of grazing than other regions, although a more detailed study would be needed to confirm this.

We did not find a strong effect of soil type, weed cover or grazing by animals such as macropods, rabbits or deer on plant survival in this trial; yet other studies suggest that these factors can be an important predictor of plant growth and survival (Perring et al. 2015). The lack of a grazing effect in our study may be partly due to the proportion of plants that were guarded, which would have reduced grazing pressure on these species. As a trial, there was a limited number of monitoring sites: more extensive sampling, and across multiple seasons, would provide greater insight into the impacts of these factors on revegetated plant communities.

Species such as some wattles and eucalypts (Eucalyptus spp.) survived well, probably because they are hardy, less palatable to herbivores, and have more generalist requirements than some other species. In comparison, Sweet Bursaria and Drooping Sheoak had low rates of survival across sites: other studies have found these species are commonly affected by grazing (Jellinek et al. 2020b).

Climate can have a significant impact on plant survival, as evidenced here by the positive relationship with mean annual rainfall. This suggests that in the future, survival of some species in
their current environment is likely to be affected by climate change that involves warmer and drier conditions (Jellinek et al. 2020b).

Monitoring of revegetation activities and associated plant survival can assist land managers and community groups to adaptively manage plantings by identifying variation among sites and species, and factors that enhance survival. While this project was undertaken voluntarily by community members, to carry out monitoring in a systematic way will require adequate resources (training and staff time) for on-ground monitoring activities, as well as funding for the coordination of an online database for data storage, collation, analysis and reporting. However, community participation in monitoring is key, no matter how small, to develop a greater understanding of which plants survive, where, and why, as this information will become increasingly important in all restoration programs under a changing global climate.

References


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