Short Report

Survival of native seedlings planted by volunteers: The Lower Cotter, ACT case study

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Summary

Volunteer labour is often used for planting native seedlings for revegetation projects. The survival of such plantings is seldom monitored and reported. The overall survival of seedlings at three years of age was assessed for eight years of plantings established by nearly 15,000 volunteers in the Lower Cotter River catchment in the Australian Capital Territory. Mean survival was 66.8% across all years. We conclude that volunteers can be effectively integrated into large-scale revegetation projects if they are well trained and organised.

Introduction

Volunteers are frequently involved in revegetation projects often funded by Australian government programs (Measham & Barnett 2009). In addition to their environmental outcomes, revegetation projects also engender a suite of ancillary benefits associated with engaging volunteers, often from urban settings, in natural-resource management (Ewing *et al.* 2013). These volunteers often have little previous experience of planting seedlings and may include children of all ages.

Given the common involvement of volunteers, the survival of seedlings planted by volunteers is seldom monitored and publicly reported. This often reflects limited funding and the short time span of funded projects (Ewing *et al.* 2013). In such cases, the use of funding generally prioritises the number of seedlings planted across the greatest area, at least cost. The decade-long revegetation of parts of the Lower Cotter Catchment is an exception

to this general approach. This 6350 ha catchment was dominated by Radiata Pine (*Pinus radiata*) plantations, established and managed by government agencies for over 50 years. These plantations were burned during a catastrophic firestorm on 18 January 2003. Subsequently, the ACT Government decided to decommission affected plantations in favour of enhancing the area as a water catchment prior to the enlargement of the Cotter Dam (Auty *et al.* 2018). Enhancement activities initially relied on natural regeneration of native woodland cover which was satisfactory over about 5000 ha of the catchment. However, due to the long period under pines, hand planting of tree and shrub seedlings was deemed necessary across targeted areas of the catchment. Mixed species plantings occurred in areas where there was little natural post-fire regeneration of native woody vegetation.

Greening Australia, an environmental not for profit organisation, was engaged by the ACT Government to coordinate planting of 500 ha in the former Pierces Creek and Uriarra plantation areas of the Lower Cotter catchment. During 12 years, between 2004 and 2015, Greening Australia engaged nearly 15,000 people who volunteered 47,000 h to plant 306,000 nursery-grown seedlings of 64 local native trees, shrubs and some ground cover species (Greening Australia 2015). During this period, a small team of volunteers established monitoring plots to assess survival and growth of most large plantings. Here, we report on the survival of these plantings established by volunteers.

Methods

The land-use history, geology and ecology of the Lower Cotter Catchment is described in detail by Auty *et al.* (2018).

Seeds planted by the volunteers were all of local provenance and seedlings were grown in a local nursery managed by Greening Australia. All plants were grown out in small (120 mm tall) forestry pots.

Planting events were conducted from autumn to spring, starting in 2004 and continuing until 2015. At planting, all volunteers, usually more than 100 people planting for half a day, were given basic training in tree planting by Greening Australia staff. These staff remained onsite during planting sessions. At most sites, seedlings were placed in holes hand dug by volunteers in mounds mechanically constructed some years earlier for replanting the pine plantation (Fig. 1). Spacing of seedlings was approximately 3–

4 m along a row and the constructed rows were 4 m apart. All seedlings were immediately hand watered (2–3 L/plant) by volunteers and plants enclosed by cardboard guards supported by two bamboo stakes.

Some blackberry control was undertaken in areas of dense infestation, otherwise, no broad-scale weed control was undertaken pre or post-planting. Pine wildings were present, but were removed by volunteers and contractors. Browsing was not a factor in the early years. Later, rabbit, hare and kangaroo grazing occurred, mitigated by tree guards.

Permanent transects were randomly located along rows after each planting event to provide a basis for ongoing monitoring. For the 2005–2007 plantings, six transects per year were established, each sufficiently long to include 20 seedlings. This design meant that approximately one transect was established per 2500 seedlings planted. For each of the 2008–12 plantings, eight transects of 10 plants were established for each planting event. These transects were randomly located in pairs along the rows of seedlings. The transects of each pair were separated by two rows of seedlings. Thus, the number of seedlings that were monitored varied between planting sites and varied between years depending on the number of planting events in each year. Seedling survival along each transect was monitored within the year of planting and subsequently monitored for the next three years post-planting. In most cases, a seedling could be identified to genus or species if it was still alive at the first monitoring date. A plant was recorded as dead if there were no green leaves, stems, or swollen lignotuberous or epicormic buds. The list of monitored species is shown in Table S1.

Due to the high diversity of plantings, there was generally insufficient data to report survival rates at the species

level. Rather, rates are reported separately by plant functional group comprising *Eucalyptus* and *Acacia* seedlings, and a group combining all other woody and herbaceous species. The effects of year of planting and plant functional group on plant survival were analysed statistically using analysis of variance (one-way ANOVA of calendar year and functional groups). Least Significant Difference (LSD) matrices were calculated to identify significant differences between years of plantings and significant differences in the survival rates of functional groups. Following the ANOVA analysis, inter-annual variation in survival between functional groups was examined using a chi-square contingency analysis. JMP software was used for all analyses.

Results

Survival at the three-year point was monitored across eight years of plantings (Table 1) and a total of 185 transects. Mean survival after three years, across all plant groups and establishment years was 66.8% (Table 1). Survival among years only differed significantly for the plantings that occurred during 2006. Rainfall during 2006 was well below average; 361 mm relative to the long-term annual average of 617 mm. Overall survival was only 37.5% for 2006. Mean survival was 69.6% for all years other than 2006.

Survival rates did not differ statistically between *Eucalyptus* and *Acacia* plantings across all years ($P = 0.81$). When 2006 was excluded from the analysis, mean survival rates of *Eucalyptus* and *Acacia* were similar (79.6% and 74.9%, respectively). Survival of non-*Eucalyptus* and non-*Acacia* woody species was significantly lower than for *Eucalyptus* plantings ($P = 0.04$).

Figure 1. A typical volunteer planting in the Lower Cotter catchment. At the time of planting (a) and three years later (b). The mechanically constructed mounds can be seen in the foreground in (a).

Table 1. Seedlings survival (%) at three years of age for eight years of plantings in the Lower Cotter Catchment, ACT, installed by volunteers supervised by Greening Australia (*n* is the number of monitored individuals, 1973 seedlings in total)

Plant functional Groups	2005	2006	2007	2008	2009	2010	2011	2012	Mean survival (%) across all years [$\pm$ SE]
Eucalypts	74.4 (43)	31.3 (16)	86.9 (68)	86.7 (337)	79.6 (54)	92 (125)	73.2 (71)	64.8 (108)	73.6 [6.8]
Acacias	96.3 (27)	34.6 (26)	93.3 (15)	70.7 (92)	73.6 (37)	67.6 (91)	65.3 (95)	57.6 (59)	69.9 [6.9]
Other woody species	– (0)	48.4 (31)	75.0 (16)	54.8 (31)	45.5 (77)	76.8 (56)	39.7 (78)	48.0 (82)	55.5 [5.2]
Herbaceous species	– (0)	33.3 (3)	– (0)	100 (10)	91.9 (37)	76.9 (65)	69.6 (69)	64.7 (51)	72.2 [8.3]
unknowns	20.0 (5)	0 (4)	0 (1)	0 (10)	0 (15)	0 (61)	0 (7)	– (0)	2.5 [2.5]
Annual survival (%) across all seedlings	78.7 (75)	37.5 (80)	85.0 (100)	80 (480)	62.3 (220)	69.1 (398)	60.3 (320)	61.7 (300)	66.8 [5.3]

Management and policy implications

There are many environmental and management factors that affect the survival of planted seedlings (Graham *et al.* 2009). These factors include the quality of seedlings from the nursery, soil preparation, weed control, use of tree guards, species choice, soil moisture conditions, herbivory and the quality of installation by the people involved (Rawlings *et al.* 2010). In our study, the planters were all volunteers with a great diversity of ages and prior experience. From our observations during planting events, some likely planting errors were that seedlings were planted too deep, too shallow, or not watered in. Despite these faults, we conclude that volunteers can contribute to successful plantings. We conclude that survival greater than 70% at three years of age for the dominant woodland canopy species (i.e. *Eucalyptus* and *Acacia*) is acceptable. Our results provide strong evidence that volunteer hand planting is a useful strategy when planting of seedlings is necessary or preferred. Volunteers are a viable alternative to techniques like contractor-based planting or direct seeding (Cuneo *et al.* 2018).

If survival of the plantings in the Lower Cotter catchment is sustained, we predict that the resulting density of surviving trees and shrubs will be likely be adequate to meet a Yellow Box woodland structure benchmark of 37–56 mature trees per hectare (table 5, Gibbons *et al.* 2010). Long-term plant densities will be next be assessed by examining survival ten years post-planting. This will be completed in 2022.

Based on our results, we suggest that when planning a revegetation planting that includes installation of seedlings, a 20–30% mortality rate should be assumed over the first three years. This mortality rate should be accommodated to achieve targeted long-term densities of mature plants. We note, however, that this expected mortality reflects the outcomes of planting in the Lower Cotter Catchment only. We are not aware of other published reports of survival rates associated with volunteer plantings in Australian woodland environments. We encourage

more organisations and projects to incorporate simple monitoring. As demonstrated in this example, monitoring itself can be completed by volunteers with sufficient training and experience.

The involvement of volunteers has many benefits. Our experience of supervising hundreds of planting events, combined with volunteer feedback, indicates that planting opportunities are viewed highly positively. Generally, volunteers enjoy the experience in an activity appropriate for all ages including families with young children and seniors with reasonable mobility. In the Lower Cotter Catchment, volunteer involvement offered positive ways to contribute to the collective response to the devastating firestorm of 18 January 2003 (Greening Australia 2015). Volunteer-based monitoring presented a meaningful pathway to sustain this engagement and its associated social benefits.

Based on evidence of adequate survival from our plantings, we suggest that government, corporate and philanthropic organisations should be encouraged to continue to support the involvement of volunteers in revegetation. In addition, we suggest that the role of volunteers can be meaningfully expanded to monitor survival. It is important to recognise that this expanded role will add to the significant financial and human resources involved in supporting volunteers. For example, Greening Australia planting events required considerable organisation as well as paid staff to be onsite with field vehicles, water tankers and refreshments. We suggest that encouraging volunteer-based monitoring of plantings can offer further justification for the worthwhile effort and resources required to support volunteer plantings.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Woodland species monitored for the 2005–2012 plantings in the Lower Cotter Cathment, ACT.