Re-establishment of the shrubby tororaro (*Muehlenbeckia astonii* Petrie), a nationally threatened plant

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CONTENTS

Abstract

Most populations of nationally threatened shrubs, including *Muehlenbeckia astonii,* are dominated by mature plants, with little evidence of recent recruitment. Restoration of these populations has been seen as a conservation management priority by the Department of Conservation. The research described here sought to quantify the effects of different grazing, weeding and companion planting treatments on such restoration. Removal of grazing has clear benefits for *Muehlenbeckia astonii* and companion plant survival and growth, with a significantly better response when both lagomorphs and stock were excluded. Weeding also had clear benefits for *Muehlenbeckia astonii* survival and growth, with unweeded plants doing significantly less well than weeded plants because of smothering by competing grasses. While there was a significant companion plant effect on the survival and growth of *Muehlenbeckia astonii*, this result is believed to be due to differences between sites rather than to a true companion planting effect. The value of the *Muehlenbeckia astonii* restoration trial will increase with time and it is recommended that the continuation of the trial with regular re-measurement be made a priority in future business planning. Research on lagomorph impact and control and on competition with invasive plants should be a high priority for the Department of Conservation. There would also be considerable value in bringing together the results of the many different restoration trials being undertaken by the Department of Conservation, Universities, and Crown Research Institutes to identify common results and to highlight areas were more research is required.

Keywords: threatened plants, restoration, grazing, weeds, management, *Muehlenbeckia astonii*, Wellington Conservancy, New Zealand

1. Introduction

The New Zealand threatened vascular flora comprises 107 taxa, with a further 307 taxa classified as declining or naturally uncommon (de Lange et al. 1999). Of the threatened taxa, 28 (26%) are shrubs, with many of these having a predominantly eastern distribution in the lower rainfall areas of the South and southern North Island. Several of these threatened shrub species appear to be facing similar threats including habitat loss, competition with invasive plants, and predation (de Lange & Silbery 1993; Molloy & Clarkson 1996; Rogers 1996; Williams et al. 1996; Widyatmoko & Norton 1997; Molloy et al. 1999). While the impacts of habitat loss can be addressed through legal protection of remnant sites and restoration programmes, the effects of competition and predation are more difficult to address, especially at a large scale. Furthermore, while restoration can be used to increase extant populations and establish new populations, restored populations still face threats associated with competition and predation.

The original justification for this research programme focused on the need to better understand the threats that shrub species face in the wild and especially the factors that are likely to limit the success of restoration programmes using these species. The intention was that the results would have wider implications for the restoration of threatened shrub species and that a manual on the restoration of woody plants would be produced. For the reasons discussed later in this report, it was felt that the production of such a manual would be inappropriate at this stage but an alternative approach to addressing the more general restoration issue is highlighted at the end of this report.

The research was initiated as part of an integrated plant conservation programme in Wellington Conservancy (Empson & Sawyer 1996), although the results will be of use to all people implementing national species recovery programmes. The research originally aimed to work with *Muehlenbeckia astonii* (Endangered) and *Pittosporum obcordatum* (Conservation Dependent). However, it was decided early on to switch from *P. obcordatum* to *Olearia gardneri* (Critically Endangered) because there was already an active restoration research programme with *P. obcordatum* (by Northland Conservancy) and because of the higher risk of extinction with *O. gardneri*. Unfortunately, problems with obtaining sufficient nursery grown plants of *Olearia gardneri* (due to the failure of the contracted nursery to deliver plants) delayed the establishment of the *Olearia gardneri* restoration trial with plants not due to be planted until 2002. However, the restoration site has been fenced (protecting remnant *O. gardneri* and *Coprosma wallii* (Declining) from cattle damage) and plants of *O. gardneri* and *C. wallii*, and of a number of associated species are being propagated ready for planting in spring 2001 and 2002. These plants have been purchased as part of this research project and the restoration trial will be co-ordinated by the Masterton Area Office with scientific input from the author. This report therefore focuses only on the *Muehlenbeckia astonii* restoration trial.

The objectives of this research were to quantify the effects of grazing, weed control and companion planting on the establishment of *Muehlenbeckia astonii* plants in a field restoration as a basis for improving future conservation plantings of this species. This report presents the results of this work and highlights issues for the future management of the *Muehlenbeckia astonii* restoration trial.

2. Study species and area

The following information on *Muehlenbeckia astonii* has been summarised from Lovell *et al.* (1991), de Lange & Silbery (1993), and de Lange & Jones (2000). *Muehlenbeckia astonii* (Polygonaceae) is a rounded, bushy, deciduous, divaricating shrub up to 3 m height that can live for at least 100 years. It is endemic to the south-eastern North Island and eastern South Island as far south as Kaitorete Spit in Canterbury and was a distinctive member of the grey scrub ecosystems (Wardle 1991) in this area, but is now considerably reduced in extent. Although it is known from 37 sites scattered throughout its historic range, it is only common at one (Kaitorete Spit), with the remaining sites containing less than three plants per site on average. It produces insect pollinated flowers with individual plants either female or 'inconstant' males. While 'inconstant' male plants occasionally produce seed through selfing, this usually has low viability. The fruit are animal dispersed, with birds and geckos thought to be important.

Ecologically, *Muehlenbeckia astonii* appears to be most common in grey scrub communities on free-draining fertile sites such as coastal sands, loess covered hill slopes and uplifted coastal terraces. It has also been recorded from ephemeral wetlands in the North Island. The sites in which it occurs typically experience summer drought (at Orongorongo station, close to the research site used here, December through February are the driest months). Several factors appear to have lead to the decline in *Muehlenbeckia astonii* including habitat loss, predation and trampling, disease, recruitment failure, introgression and competition. Because of these factors, *Muehlenbeckia astonii* has been listed as Endangered in the most recent listing of New Zealand's threatened plants (de Lange et al. 1999).

This research was undertaken at Turakirae Head, between Wellington and Palliser Bay at the southern extremity of the Tararua Ecological District (Fig. 1). The area comprises a series of uplifted beach ridges, the most recent dating from the 1855 Wellington earthquake, and experiences an equable, but windy climate. Mean annual rainfall (1951–80 normal) is 1125 mm at Orongorongo station 2 km to the north-west (Anon. 1983a). At Cape Palliser, 35 km to the south-east, mean annual temperature is 14.0°C, with January mean maximum and minimum temperatures of 21.6°C and 14.1°C and July mean maximum and minimum temperatures of 12.3°C and 7.2°C (Anon. 1983b). *Muehlenbeckia astonii* still occurs to the east of the Turakirae Head study site although not at the study site itself. The species that are present are, however, typical of the species *Muehlenbeckia astonii* grows within the general area. The study site is subjected to regular grazing by domestic stock (only sheep were observed during our visits) and there was evidence of rabbits and/or hares, and possums also being present. The area is open to the public, but access is by foot and vandalism has not been a problem.

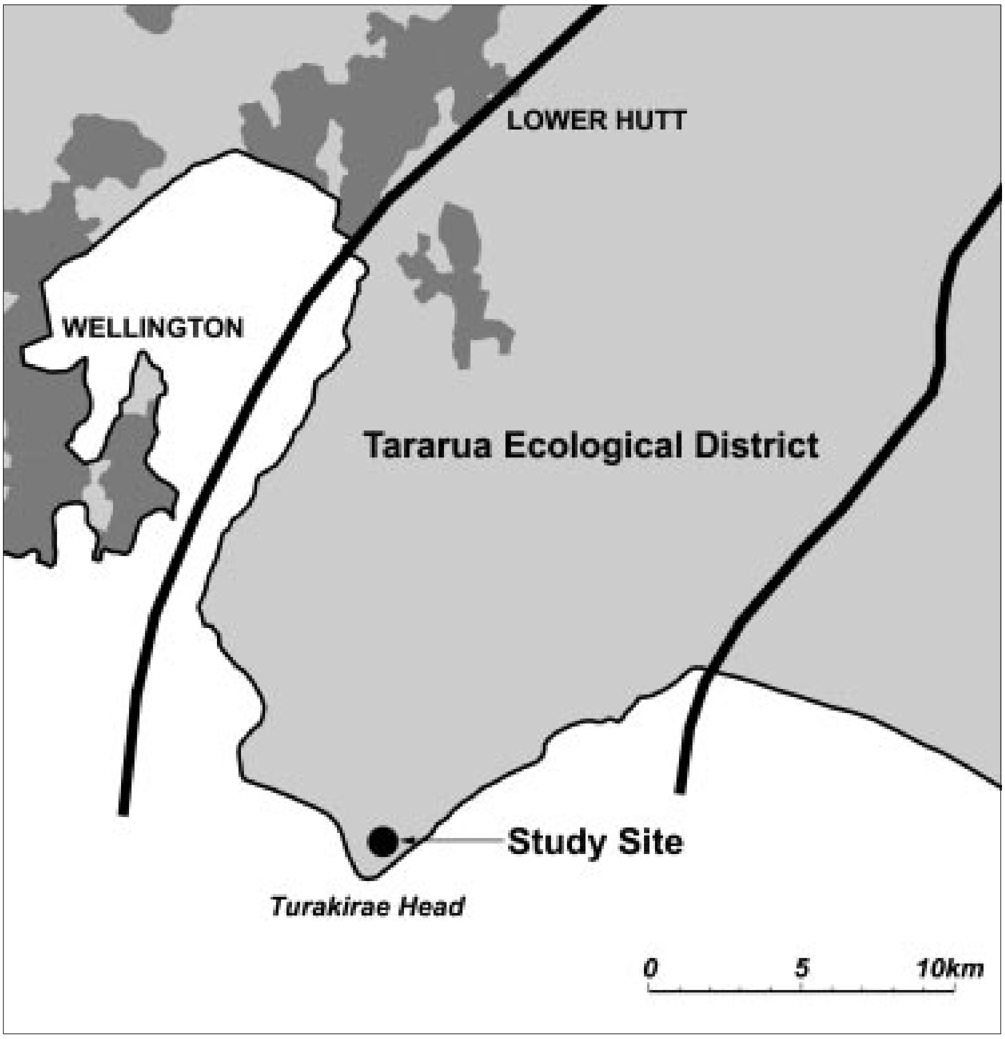

Figure 1. Location of the Turakirae Head *Muehlenbeckia astonii* restoration trial.

3. Methods

3.1 SEED GERMINATION

Seed was collected on 7 February 1997 from *Muehlenbeckia astonii* plants growing in cultivation in Hutt Valley sourced from the Honeycomb Light population in the eastern Wairarapa. Seeds were separated from the swollen flower remnants and stored in a paper bag at room temperature until the germination trial commenced on 25 February 1997. Seeds were placed on moist filter paper in a petri dish, with five petri dishes containing 20 seeds each used for each treatment. Seeds were germinated in a Contherm Scientific 630 growth cabinet under a day length/temperature cycle comprising 10 hrs dark at 15°C and 14 hrs light (c. 35 $Em^{-2}d^{-1}$) at 25°C corresponding approximately to spring/summer conditions. Five treatments of 100%, 75%, 50%, 25% and 0% full growth cabinet light were obtained using shade cloth frames. Because of resource limitations there was no replication of treatments (cf. Morrison & Morris 2000).

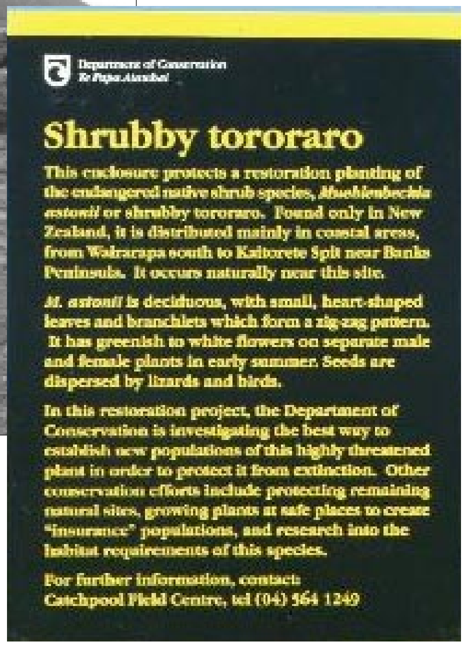

Figure 2. *Muehlenbeckia astonii* restoration trial site looking east with the enclosed area to the left of the fence (photo July 2000). *Inset right:* The information sign on the trial fence.

Petri dishes were inspected every 2–3 days and any germinated seeds removed. The trial ceased after 120 days when no germination had occurred for 37 days.

3.2 RESTORATION TRIAL FIELD METHODS

After an initial site inspection an area of c. 0.7 ha comprising open pasture with small patches of coastal scrub amongst rocks was chosen. This area was topographically uniform (Fig. 2) and had easy access from existing 4-wheel drive tracks. We used a nested experimental design with grazing as the major effect for the trial. We established two fenced areas and one unfenced area within which we located the weeding and companion planting treatments (Fig. 3). The two fenced areas were bounded by a common 7-wire stock proof fence, with c. $^{1}/_{3}$ of the area completely fenced with netting to exclude

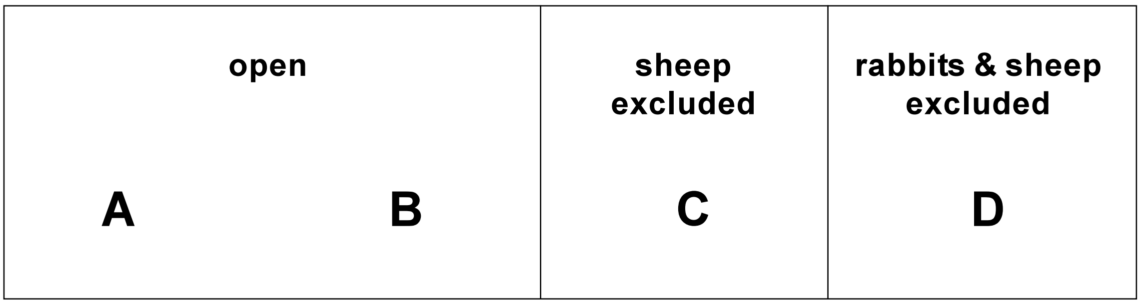

Figure 3. Restoration trial layout. A=companion plants (6 replicates). B=Three competition treatments of 6 replicates each. C=companion plants (6 replicates). D=Three competition treatments of 6 replicates each. E=Three competition treatments of 6 replicates each.

lagomorphs (hares and rabbits). The unfenced area was located away from the fenced area to ensure that stock access was not modified by the presence of the fences.

We established three weeding treatments (no weeding, one-off weeding, and annual weeding) within each of the three grazing treatments (lagomorph excluded, stock excluded, and open). Weeding involved a mixture of hand releasing and chemical spraying (Roundup G2) and was undertaken during winter. The weeding treatments nested within the grazing treatments are referred to as experiment 1 (grazing and weeding). In the stock excluded and open grazing treatments we also established a companion planting treatment. Here we planted the shrubs *Olearia solandri* and *Coprosma propinqua* with the *Muehlenbeckia astonii* plants. This treatment was not weeded and is referred to as experiment 2 (grazing and companion plants). In addition, the growth of the two companion plants, *Olearia solandri* and *Coprosma propinqua*, was compared between the two grazing treatments and this is referred to as experiment 3 (companion plant growth).

Six replicate plots were established for each treatment with 20 *Muehlenbeckia astonii* individuals planted per plot. For the weeding treatments each replicate plot was randomly assigned within each grazing treatment. The companion planting plots were located separate from the weeding plots to ensure that there was no interaction between these two treatments.

Plants of *Muehlenbeckia astonii*, *Olearia solandri,* and *Coprosma propinqua* were grown from cuttings by Plantwise Nursery in Lower Hutt. *Olearia solandri* and *Coprosma propinqua* cuttings were sourced from plants at Cape Turakirae, where they are both common, while *Muehlenbeckia astonii* cuttings were sourced from breeding populations of plants originally from Fitzroy Bay, Baring Head, Khyber Pass, Orongorongo River mouth, and Turakirae Head (John Sawyer pers. comm. September 1997). Cuttings were collected in September 1997 and grown on until planting in September 1998.

Individual plots involved planting *Muehlenbeckia astonii* plants at a 1 m spacing in blocks of 4 × 5 plants (20 plants per plot). In the companion plant plots, *Muehlenbeckia astonii* plants were located at 1.5 m spacing, with companion plants located between these and forming two additional lines around the outside of the *Muehlenbeckia astonii* plants. All plants were measured in November 1998 and the first weeding treatment applied at the same time. Measurements made were basal stem diameter (immediately above the root collar), plant height, and canopy spread (the greatest spread and the axis perpendicular to this). The status of plants (alive and dead) was also noted. The plants were remeasured in May 1999 and June 2000, and weed treatments applied in May 1999 and May 2000.

3.3 STATISTICAL ANALYSES

Four variables were derived from the field measurements and used in the analyses. Plant survival was calculated as the proportion of plants alive in 1999 and 2000 relative to the number present in November 1998 for *Muehlenbeckia astonii*, *Olearia solandri* and *Coprosma propinqua*. Basal stem diameter growth was expressed as the difference in diameter between 1999 and 2000 relative to 1998 for *Muehlenbeckia astonii*. Canopy volume was calculated using the formula of a sphere using the height and canopy dimensions of *Muehlenbeckia astonii*. Measurements for 1999 and 2000 were again expressed relative to 1998. Height growth was expressed as the difference in height between 1999 and 2000 relative to 1998 for *Olearia solandri* and *Coprosma propinqua*.

Data were tested for normality using the Shapiro-Wilk test and transformed when not normally distributed (arcsin-sqrt for proportional data and log for other data). A nested analysis of variance (anova), with weeding (three treatments) or companion planting (two treatments) nested within grazing (three treatments), was used to test the significance of the different treatments on *Muehlenbeckia astonii* survival and growth. A single factor anova was used to test the significance of two grazing treatments (no stock and open) on *Olearia solandri* and *Coprosma propinqua* survival and growth. *A posteriori* least squares means tests were used to test for significant differences between individual means. All analyses were undertaken in SAS (version 8) using PROC UNIVARIATE and PROC GLM.

4. Results

4.1 SEED GERMINATION

Seeds commenced germination after 25 days, but overall germination was very low, ranging from 1–6% across the different treatments (Table 1). There was no significant difference in germination between treatments ($F = 0.70$, $P = 0.6006$), although there was a trend of increasing germination with decreasing light. The number of petri dishes with no germination was also highest in the two highest light treatments (Table 1).

TABLE 1. *Muehlenbeckia astonii* SEED GERMINATION (PROPORTIONS) AFTER 120 DAYS.

TREATMENT	MEAN ± SE	NUMBER OF REPLICATES WITH ZERO GERMINATION
Full light	0.01 ± 0.01	4
75% full light	0.02 ± 0.02	4
50% full light	0.04 ± 0.02	2
25% full light	0.04 ± 0.03	3
No light	0.06 ± 0.04	2

N = 5 replicates of 20 seeds for each treatment

4.2 EXPERIMENT 1 (GRAZING AND WEEDING TREATMENTS)

While grazing had a significant effect on survivorship, diameter growth, and canopy growth of *Muehlenbeckia astonii* plants in 1999, the effect of grazing was significant only for survivorship in 2000 (Table 2). In 1999 all *Muehlenbeckia astonii* plants survived under both grazing exclusion treatments (F = 21.00, P < 0.001), but in 2000 survivorship was not significantly different between the open and no stock treatments, and survivorship was significantly lower in these than in the treatment with lagomorphs excluded (F = 10.01, P < 0.001). Stem diameter growth showed a significant grazing effect in 1999 (F = 25.36, P < 0.001), with significant differences between treatments with increasing growth with increasing grazing exclusion. However, in 2000 there was no significant grazing effect (F = 0.61, P = 0.548). While there was a significant grazing effect on canopy volume in 1999 (F = 6.51, P = 0.003), the two grazing exclusion treatments had negative canopy growth while the plants exposed to grazing increased in volume. The grazing effect was non-significant in 2000 (F = 1.64, P = 0.217).

TABLE 2. MEAN ± SE *Muehlenbeckia astonii* SURVIVORSHIP, STEM DIAMETER GROWTH AND CANOPY VOLUME GROWTH (VALUES EXPRESSED AS DIFFERENCES FROM 1998) UNDER THREE GRAZING TREATMENTS AT TURAKIRAE HEAD.

	SURVIVORSHIP (PROPORTIONS)		STEM DIAMETER GROWTH (mm)		CANOPY VOLUME GROWTH (mm^3)	
GRAZING	1999	2000	1999	2000	1999	2000
Open	0.917[a] ±0.023	0.178[a] ±0.035	0.18[a] ±0.14	1.83[a] ±0.25	924[a] ±227	854[a] ±503
No stock	1.000[b] ±0	0.272[a] ±0	0.61[b] ±0.15	1.86[a] ±0.32	-1045[b] ±458	670[a] ±936
No lagomorphs	1.000[b] ±0	0.433[b] ±0	1.19[c] ±0.16	1.53[a] ±0.15	-932[b] ±644	4563[a] ±1824

N = 18 for each treatment
Means in the same row followed by the same letter are not significantly different at P < 0.05 (LS means *a posteriori* test).

Muehlenbeckia astonii survivorship and stem diameter growth was in general significantly greater with weeding than without weeding (Table 3). While the weeding effect on survivorship was not significant in 1999 (F = 0.67, P = 0.675), there was a strong and significant effect in 2000 (F = 11.68, P < 0.001), although no difference is apparent between the one-off weeding and annual weeding, both of which resulted in greater survivorship than no weeding. Stem diameter growth was also greatest with weeding, with a significant effect in 1999 (F = 10.95, P < 0.001) and 2000 (F = 3.03, P = 0.022). Again the results suggest little difference between one-off and annual weeding. The weeding effect was similar in all three grazing treatments for both survivorship and stem diameter growth. While a significant weeding effect was apparent in canopy volume in 1999 (F = 2.68, P = 0.26), there was no effect in 2000 (F = 0.47, P = 0.797). Furthermore, significant differences in canopy volume between individual weeding treatments occurred in only one grazing treatment (no lagomorphs) in 1999, with greatest growth in the once-off weeding treatment.

TABLE 3. MEAN ±SE *Muehlenbeckia astonii* SURVIVORSHIP (PROPORTION OF ORIGINAL PLANTS), STEM DIAMETER GROWTH AND CANOPY VOLUME GROWTH (VALUES EXPRESSED AS DIFFERENCES FROM 1998) UNDER THREE WEEDING TREATMENTS NESTED WITHIN THREE GRAZING TREATMENTS AT TURAKIRAE HEAD.

	SURVIVORSHIP (PROPORTIONS)			STEM DIAMETER GROWTH (mm)			CANOPY VOLUME GROWTH (mm^3)		
GRAZING>>	OPEN	NO STOCK	NO LAGOM.	OPEN	NO STOCK	NO LAGOM.	OPEN	NO STOCK	NO LAGOM.
Weeding frequency 1999									
None	0.950^{a}	1.000^{a}	1.000^{a}	−0.43^{a}	−0.10^{a}	0.73^{a}	935^{a}	−1805^{a}	−2813^{a}
	±0.022	±0	±0	±0.10	±0.10	±0.20	±343	±378	±813
Once	1.933^{a}	1.000^{a}	1.000^{a} (0)	0.57^{b}	0.8^{b}	1.82^{b}	1301^{a}	−1441^{a}	842^{b}
	±0.021	±0	±0	±0.22	±0.11	±0.28	±433	±1094	±1271
Annual	1.867^{a}	1.000^{a}	1.000^{a}	0.40^{b}	1.13^{b}	1.03^{a}	536^{a}	112^{a}	−823^{ab}
	±0.061	±0	±0	±0.14	±0.23	±0.06	±400	±619	±780
Weeding frequency 2000									
None	0.050^{a}	0.000^{a}	0.167^{a}	0.73^{a}	–	0.90^{a}	−1287^{a}	–	6081^{a}
	±0.022	±0	±0.056	±0.32	–	±0.19	±1412	–	±5251
Once	0.283^{b}	0.317^{b}	0.483^{b}	2.02^{b}	1.44^{a}	1.67^{ab}	1538^{a}	−873^{a}	1826^{a}
	±0.060	±0.119	±0.105	±0.44	±0.58	±0.24	±599	±1590	±2016
Annual	0.200^{b}	0.500^{b}	0.650^{b}	2.18^{b}	2.21^{a}	1.92^{b}	1242^{a}	1955^{a}	6034^{a}
	±0.051	±0.967	±0.043	±0.27	±0.31	±0.14	±659	±893	±2328

N = 6 for each treatment combination
For each year, means in the same row followed by the same letter are not significantly different at $P < 0.05$ (LS means *a posteriori* test)

4.3 EXPERIMENT 2 (GRAZING AND COMPANION PLANT TREATMENTS)

A significant companion planting effect occurred in 1999 for *Muehlenbeckia astonii* survivorship, diameter growth, and canopy growth, but the only significant effect in 2000 was for survivorship (Table 4). Survivorship was significantly higher with companion planting than without in both years (F = 5.00 and 7.08, P = 0.017 and 0.005 in 1999 and 2000 respectively), although individual means were only significantly different in the open grazing treatment in 1999 and the stock excluded treatment in 2000. While the overall effect of companion planting on stem growth was significant in 1999 (F = 6.04, P = 0.009), only the no stock means were significantly different. The effect of companion planting was not significant in 2000 (F = 3.01, P = 0.117).

While significant differences in the survivorship and growth of *Muehlenbeckia astonii* plants were obtained between companion planting treatments (Table

TABLE 4. MEAN ±SE *Muehlenbeckia astonii* SURVIVORSHIP (PROPORTION OF ORIGINAL PLANTS), STEM DIAMETER GROWTH AND CANOPY VOLUME GROWTH (VALUES EXPRESSED AS DIFFERENCES FROM 1998) UNDER TWO COMPANION PLANTING TREATMENTS NESTED WITHIN TWO GRAZING TREATMENTS AT TURAKIRAE HEAD.

	SURVIVORSHIP (PROPORTIONS)		STEM DIAMETER GROWTH (mm)		CANOPY VOLUME GROWTH (mm^3)	
GRAZING>>	OPEN	NO STOCK	OPEN	NO STOCK	OPEN	NO STOCK
Companion plants 1999						
None	0.950[a]	1.000[a]	-0.43[a]	-0.10[a]	935[a]	-1805[a]
	±0.022	±0	±0.10	±010	±343	±378
Olearia & *Coprosma*	1.000[b]	1.000[a]	-0.07[a]	0.43[b]	-1110[b]	2435[b]
	±0	±0	±0.13	±0.17	±370	±972
Companion plants 2000						
None	0.050[a]	0.000[a]	0.73[a]	-	-1287[a]	-
	±0.022	±0	±0.32	-	±1412	-
Olearia & *Coprosma*	0.167[a]	0.350[b]	1.95[a]	1.76	1740[a]	6275
	±0.076	±0.134	±0.72	±0.196	±2431	±1045

N = 6 for each treatment combination
For each year, means in the same row followed by the same letter are not significantly different at P < 0.05 (LS means *a posteriori* test)

4), these differences reflect a flaw in the experimental design. Because the companion planting treatment and non-treatment areas were spatially separated for both the open and no stock grazing treatments, the differences observed cannot be realistically attributed to any companion planting effect. This conclusion is supported by the very poor survivorship and growth of the companion plantings (see Table 5). For these reasons the companion planting results are not discussed further here.

4.4 EXPERIMENT 3 (GRAZING AND COMPANION PLANT GROWTH)

Significant differences in the survivorship of *Olearia solandri* companion plants occurred in both 1999 (F = 6.72, P = 0.027) and 2000 (F = 16.18, P = 0.002), with greatest survival when stock were excluded (Table 5). Although survival of the other companion species, *Coprosma propinqua*, was also greatest in the absence of stock, the difference was not significant in either 1999 (F = 2.27, P = 0.163) or 2000 (F = 0.40, P = 0.539) reflecting high variability between individual replicates. A similar result occurred when height growth was considered, with significantly greater *Olearia solandri* height growth with stock excluded in 1999 (F = 18.02, P = 0.002) and 2000 (F = 14.32, P = 0.004). However, no significant differences were observed for *Coprosma propinqua* (1999, F = 0.52, P = 0.521; 2000, F = 4.35, P = 0.128), although height growth was on average greater in the absence of stock (Table 5).

TABLE 5. MEAN ±SE COMPANION PLANT SURVIVORSHIP (PROPORTION OF ORIGINAL PLANTS) AND PLANT HEIGHT (VALUES EXPRESSED AS DIFFERENCES FROM 1998) UNDER TWO GRAZING TREATMENTS AT TURAKIRAE HEAD.

	SURVIVORSHIP		HEIGHT GROWTH (cm)	
GRAZING>>	OPEN	NO STOCK	OPEN	NO STOCK
Companion plants 1999				
Olearia solandri	0.355 ±0.078	0.645 ±0.048	–4.72 ±2.37	5.23 ±0.86
Coprosma propinqua	0.107 ±0.043	0.267 ±0.078	1.60 ±2.11	8.82 ±8.55
Companion plants 2000				
Olearia solandri	0.080 ±0.028	0.282 ±0.036	–1.62 ±2.91	9.62 ±1.25
Coprosma propinqua	0.030 ±0.020	0.053 ±0.026	2.55 ±3.35	8.50 ±1.07

N = 6 for each treatment combination

5. Discussion

5.1 LIMITATIONS OF STUDY

The research described in this report addresses some critical issues in the recovery of threatened woody shrubs. However, the experimental design used has a number of limitations. The most important is the lack of replication of the three grazing treatments, with just one of each. This arose because we lacked the resources to establish further fencing, but does suggest some caution in interpretation. Nevertheless, the grazing results were so pronounced, and broadly similar to those found in other studies, suggesting that despite this experimental limitation they do describe a biological meaningful effect. The problem with the spatial separation of the companion planting treatments has already been discussed and suggests that this comparison is biologically invalid. Finally, this experiment considered the establishment of one-year old *Muehlenbeckia astonii* plants established from cuttings. As such the results provide no insight into the factors that limit the establishment and initial growth of plants of this species. Despite these limitations, the results still provide useful pointers on the effects of grazing and weeding on plant survival and growth that have more general applicability in threatened species restoration.

5.2 GRAZING EFFECTS

Removal of grazing has clear benefits for *Muehlenbeckia astonii* and companion plant survival and growth, with both showing significant increases in the absence of grazing (Tables 2 and 5). Three main observations arise from these results. The first is that when both stock and lagomorphs are excluded (2000 results only), *Muehlenbeckia astonii* survivorship is nearly double that when stock alone are excluded (43% cf. 27%). This suggests that removal of stock grazing by itself may be insufficient to ensure good survivorship of *Muehlenbeckia astonii* plantings. While the effect of stock on native plants is well known, the impacts of lagomorphs versus stock is less well understood. Certainly, the impact of lagomorphs on indigenous vegetation has been highlighted in several studies (Blay 1989; Rose & Platt 1992; Walker 2000). Examples of lagomorph browse of threatened shrub species have been documented (Molloy & Clarkson 1996). Ingrid Grüner (pers. comm. September 2000). de Lange & Silbery (1993) observed that rabbits and hares can prevent regeneration and severely damage individual plants of *Muehlenbeckia astonii*. Rose & Platt (1992) have shown that even in the absence of stock grazing, hare browsing can still inhibit *Chionochloa macra* vegetation recovery and seedling regeneration supporting the survivorship results for *Muehlenbeckia astonii* recorded here.

While there were significant differences in *Muehlenbeckia astonii* survivorship in both years, differences in growth (stem diameter and canopy volume) between the grazing treatments were only apparent in 1999 (Table 2). One possible reason for this is that many of the weakest plants were still alive in 1999, but were dead by the 2000 remeasurement (i.e. only the 'winners' survived through to 2000). Results from other studies suggest that there should be ongoing impacts from stock grazing and lagomorph browsing, at least until the plants are tall enough to escape this. At present they are still readily accessible to both stock and lagormorphs. Future remeasurements should help clarify this situation.

In contrast to *Muehlenbeckia astonii*, the companion plant *Olearia solandri* showed significant increases in survivorship and height growth in the absence of grazing in both 1999 and 2000 (Table 5), although the other companion species, *Coprosma propinqua*, showed no significant differences in either year. It may be that *Olearia solandri* is more palatable than either *Muehlenbeckia astonii* or *Coprosma propinqua*, although general experience with lagomorph impacts suggests that *Coprosma propinqua* is also very susceptible to rabbit and hare browse (Lisa Langer pers. comm. September 2000; D.A. Norton pers. obs.). The lack of a significant difference with this species reflects very large variances.

Our grazing results strongly support the identification of grazing as a major threat to the regeneration and growth of threatened New Zealand shrubs (de Lange & Silbery 1993; Molloy & Clarkson 1996; Shaw & Burns 1997; Widyatmoko & Norton 1997). More interestingly, our results are in general agreement with those of Rose & Platt (1992) and suggest that even in the absence of stock grazing, lagomorphs can still have a major impact on *Muehlenbeckia astonii* survivorship.

5.3 WEEDING EFFECTS

The importance of competition with invasive weeds has been highlighted in many studies of threatened New Zealand species including both shrubs (de Lange & Silbery 1993; Rogers 1996; Williams et al. 1996; Widyatmoko & Norton 1997; Molloy et al. 1999) and herbs (Morgan & Norton 1992; Molloy 1994). For shrubby species, the problem generally arises because of the invasion of potential regeneration sites (e.g. disturbed sites). This results in the failure of seeds to germinate, or of seedlings to establish, rather than resulting in the smothering of mature plants. Certainly the predominance of older individuals is a common feature of many threatened shrub species, and this is commonly assumed to reflect a failure in regeneration due, at least in part, to competition. However, experimental evidence for this relationship is weak.

The results of the present study strongly suggest that competition with herbaceous plants can limit the survivorship and growth of *Muehlenbeckia astonii* plants. A significant weeding effect was apparent for both survivorship and stem diameter growth, but not for canopy volume, although there was no difference between the single and annual weeding treatments. Weeding reduces the smothering of the *Muehlenbeckia astonii* plants that is commonly observed in unweeded plots (Fig. 4) and obviously the benefits of the single weeding are still evident one year later. There was, however, no evidence to suggest any interaction between weeding and grazing, with similar survivorship and stem diameter growth patterns in both grazed and ungrazed plots. The lack of any significant response in canopy volume may in part relate to canopy dieback after planting, with the plants only slowly regaining the lost canopy volume in the windy coastal environment at Turakirae Head. In contrast, *Muehlenbeckia astonii* plantings of the same age at the Catchpool field base are substantially larger. *Muehlenbeckia astonii* plants differ from many other divaricating plants in that new shoots quickly overtop older shoot systems (Lovell et al. 1991) and are, therefore, capable of rapid canopy volume expansion under favourable conditions. However, this type of growth also

Figure 4. Smothering of a *Muehlenbeckia astonii* plant by the grass sward (photo July 2000).

means that new foliage is vulnerable to dieback under adverse environmental conditions. Because of the dieback and slow recovery of the *Muehlenbeckia astonii* plantings at Turakirae Head it is likely that any effects of weeding may become more apparent in the next couple of years as plants overcome the initial dieback.

The results presented here suggest that weed control in the early stages of restoration is beneficial. However, as plants become taller, the need for weed control will diminish and at some point shading from the growing canopy will suppress any remaining weeds. The results are unclear on the frequency of weed control, although there is a strong suggestion that annual weeding may not be necessary, at least at this site. Biennial weeding may be sufficient to enhance plant survivorship and growth. However, at less 'difficult' sites biennial weeding may be insufficient.

5.4 HABITAT RESTORATION

One of the original intentions of this research was to assess the potential for restoring the shrubland habitat within which *Muehlenbeckia astonii* occurs. Habitat restoration is important, as plants like *Muehlenbeckia astonii* do not occur in isolation in the field and the grey scrub community within which this species occurs provides habitat for the animal dispersers needed to remove fruit and deposit seed in suitable regeneration sites. de Lange & Silbery (1993) suggested that the common gecko (*Hoplodactylus maculatus*) is a primary disperser of *Muehlenbeckia astonii*, although birds have also been observed feeding on fruit (de Lange & Jones 2000). Recent research with the common gecko on Mana Island (Wotton 2000) showed that this species is a major consumer of fruit (*Coprosma propinqua* in this case) and that ingested seeds have germination potential and can be dispersed for distances up to 9.3 m from parent plants. Habitat restoration would presumably provide the conditions necessary for the occurrence of species like the common gecko (e.g. through the presence of other food sources such as *Coprosma propinqua*).

While companion plantings were undertaken as part of this research, the experimental design was incorrect, which meant that the observed differences could not be validly interpreted. Furthermore, even if the experimental design had been appropriate, insufficient time had elapsed to allow evaluation of the companion planting trial. From a research perspective, it would have been better if the companion plantings had been established 2–3 years prior to the *Muehlenbeckia astonii* plants, but obviously this amount of lead-time is difficult to build into a short-term research contract. Despite this, it would seem important that future research trials address this question.

5.5 STATUS OF *Muehlenbeckia astonii*

The total number of wild *Muehlenbeckia astonii* plants in Wellington Conservancy prior to this study was c. 50, all mature individuals with no known regeneration. 1336 *Muehlenbeckia astonii* plants were established at the start of this trial and by May 2000 345 (25.8%) were still alive. Even if survival over the next two years is around 25%, there are still likely to be some 80–90 *Muehlenbeckia astonii* plants present, more than doubling the current Wellington Conservancy population.

5.6 FUTURE MANAGEMENT OF THE *Muehlenbeckia astonii* RESTORATION TRIAL

This study has provided some important information on the survival and growth of *Muehlenbeckia astonii* plants in a field restoration trial. However, the trial is only two years old and it seems premature at this stage to work the results up for formal publication in a scientific journal. It is likely that the value of the trial will increase with time, especially as other aspects of the *Muehlenbeckia astonii* community are investigated across the different treatments (e.g. gecko response to the different grazing treatments). Every effort should be made to continue the trial at least for the next 5–10 years.

I have the following recommendations for the future management of the *Muehlenbeckia astonii* trial:

- Wellington Conservancy should continue the trial with regular re-measurement a priority for future business planning
- Annual weeding should be maintained and expanded to include plants in the one-off weed treatment
- The companion planting experiment should be discontinued because the measured effect is spurious (see above) and the annual weed treatment should be applied to the companion planting treatment plots.
- All plants in the restoration trial should be re-measured in 2002, using the same methods described here, with a full analysis of the results, and formal publication in a scientific journal

6. Conclusions

This research has reiterated the major effect that grazing and competition have on the growth of threatened shrubs such as *Muehlenbeckia astonii*. While it is possible to manage these threats on a small scale, large scale control of lagomorph grazing and weed competition in particular is likely to be difficult, and more work is required to develop efficient and cost effective methods for doing this. While it is relatively easy to remove stock from shrubland communities (e.g. through appropriate fencing), the impact of lagomorphs is going to be difficult to address in conservation management, especially as increasing areas of land are added to the public conservation estate through tenure review. Yet, if the impacts of these animals cannot be managed, it will be increasingly difficult to sustain a number of threatened species in the wild in the long-term. In the same manner, the impacts of competition with the invasive grasses and forbs that are sometimes dominant in these ecosystems also poses very real problems for the long-term persistence of these communities. While these issues have been highlighted in recovery plans for both *Muehlenbeckia astonii* (de Lange & Jones 2000) and *Hebe cupressoides* (Norton 2000), research on lagomorph impact and control and on competition with invasive plants must be a high priority.

The research described here is not unique and there are a number of similar trials being undertaken in different Department of Conservation Conservancies, as well as related work within Universities and Crown Research Institutes. Unfortunately much of this work has never been published. Because of this there is a very real chance that the same questions will be examined independently and that there will be relatively little interchange of ideas and/or wider dissemination of trial results. There would, therefore, seem to be real merit in trying to bring together the results of these different research trials in some form, to identify common results and to highlight areas where more research is required. Then the production of a manual on restoration of threatened woody plants would be a more viable proposition.

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