Control of the exotic bulb, Yellow Soldier (*Lachenalia reflexa*) invading a Banksia woodland, Perth, Western Australia

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Summary In recent times managers have become increasingly aware of the South African bulbous species Yellow Soldier (*Lachenalia reflexa*) becoming a serious weed of bushland on the Swan Coastal Plain. In 1998, trials were implemented to investigate control options for Yellow Soldier invading the understorey of a Banksia (*Banksia attenuata*) Woodland west of Perth. Our trials showed that hand removal over two seasons left all natives intact but was very labour intensive, only reducing cover of Yellow Soldier by 44%. It also triggered germination by ephemeral weeds. Wiping the leaves of individual plants with a 10% glyphosate solution was not effective and was also highly labour intensive. Spot spraying with metsulfuron methyl at 0.2 g/15 L (5 g/ha) reduced the cover of Yellow Soldier by 65%, was easier to implement and appeared to have had insignificant effects on natives. We hope that this trial will encourage other workers in the field to undertake controlled trials to refine treatments at restoration sites.

Key words *biological invasions, bulbs, bush regeneration, metsulfuron methyl, weeds.*

Introduction

While land clearing is still a major problem, the Banksia Woodlands of Western Australia's Swan Coastal Plain (Fig. 1) are becoming increasingly appreciated for their high species diversity and rare aesthetic qualities. Banksia Woodlands are widespread on the plain, generally dominated by *Banksia attenuata* and *B. menziesii* but sometimes co-dominating with Jarrah (*Eucalyptus marginata*) or with Tuart (*E. gomphocephala*). Conservation management of these sites has become a high priority. Once protected from clearing, however, these woodlands are still susceptible to invasion by weeds, particularly bulbous and cormous weeds that readily colonize the woodlands' naturally open structure. Throughout the Perth area, increasing numbers of bush regeneration groups involved in weed control find weeds like Yellow Soldier (*Lachenalia reflexa*) problematic (Box 1).

There a number of difficulties associated with controlling bulbous weeds such as *Lachenalia* in the understorey of Banksia Woodlands. They often invade undisturbed bushland and grow very closely among native plants. The labour intensive nature of hand removal is often impractical on a larger scale. Furthermore, given the high densities at which these bulbous weeds often occur, the resulting soil disturbance can encourage establishment of other weeds (Grime 1979; Hobbs & Atkins 1988; Hobbs 1991).

Chemical control options are limited. The non-selective herbicide glyphosate has been found to be effective against a number of South African bulbous and cormous species including Freesia (*Freesia alba* × *leichtlinii*), *Ixia* spp. (Dixon & Keighery 1995) and Watsonia (*Watsonia* spp.) (Day 1993). This is an acceptable option when the weeds occur in dense monocultures. Unfortunately such weeds generally grow closely among native vegetation and the use of non-selective herbicides will inevitably lead to unacceptable off-target damage unless the herbicide application is very carefully targeted.

Following the introduction of the sulfonylurea group of herbicides in early 1980s, metsulfuron methyl in particular has been found to be very effective against a number of South African bulbous/cormous species. These include Soursob (*Oxalis pes-caprae*) (Parsons & Cuthbertson 1992; Peirce 1998); Bridal Creeper (*Asparagus asparagoides*) (Pritchard 1991; Dixon 1996); Freesia (Dixon 1998); and Harlequin Flower (*Sparaxis bulbifera*) (Meney 1999). Interestingly, observations from these studies and others suggest that many native species are resistant to the effects of metsulfuron methyl at rates of 5 g/ha and below (Dixon 1996; Meney 1999; Moore 1999).

In the present study we investigate the effectiveness of hand removal, and two herbicide treatments on the control of

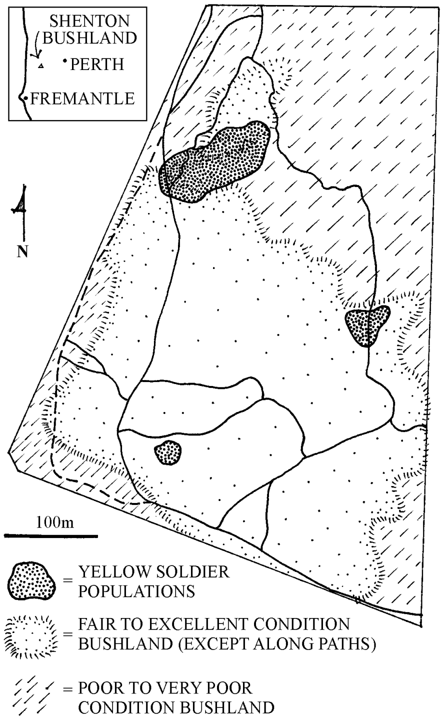

Figure 1. Distribution of the three populations of Yellow Soldier in Shenton Bushland and vegetation condition across the site. (Solid lines are surfaced paths, dashed lines are unsurfaced paths.) [Map adapted from Ecoscape 1994]

Yellow Soldier. At the same time we record the impact of each treatment on various components of the flora of a Banksia Woodland. All scientific names of taxa are consistent with Paczkowska and Chapman (2000).

The site

Shenton Bushland, a 21-ha remnant of Banksia Woodland (here co-dominating with Jarrah), lies on Spearwood dunes approximately 8 km west of the centre of Perth (Fig. 1). With only 18% of the vegetation complex remaining uncleared, the bushland is considered regionally significant (Department of Environmental Protection 2000). These woodlands occur on pale yellow to grey calcareous sands derived from Tamala limestone and are very species rich, with an average 55.2 species occurring in a 10 m × 10 m plot (Gibson *et al.* 1994). For Shenton Bushland as a whole, 109 species of natives and 40 species of weeds have been recorded and around 50% of the bushland is in fair to excellent condition. The remainder varies from fair to poor with areas of severe localized disturbance (Ecoscape 1994; Department of Environmental Protection 2000) (Fig. 1). The trial was located in a smaller population of Yellow Soldier in very good condition bushland on the eastern side of the reserve (Fig. 1).

A large section of Shenton Bushland including the study site was burnt in October 1997. The first sampling took place in August 1998. As a part of the ongoing rehabilitation program for the bushland, a large area including the trial site was sprayed with the grass-selective herbicide Fusilade® (Crop Care, Pinkenba, Queensland, Australia) at 4 L/ha (10 mL/L) in July 1999 and again in July 2000 to control introduced Perennial Veld Grass (*Ehrharta calycina*). The herbicide was applied from a 400 L tank with a hand-held hose. In the areas where Perennial Veld Grass occurred the vegetation was blanket sprayed. This treatment involved the trial areas but is unlikely to have affected Yellow Soldier (or anything but grasses) as Fusilade® is primarily a grass selective herbicide. At lower rates (1 L/ha) it is known to have little impact on native plants including native perennial grasses (Hitchmough *et al.* 1994; Davies 1997). At 4 L/ha Fusilade® appears to have little impact on non-grasses (K. Brown, unpubl. data, 1998, 1999, 2000, 2001). Other treatments identified as being required by the site's rehabilitation plan, including control of Freesia and Watsonia (*Watsonia meriana*), were not carried out in the trial area.

How we planned and monitored the trials

Our initial goal was to trial two control methods: hand removal and glyphosate herbicide (wiped on individual leaves). Plots 2 m × 2 m were laid out in a randomized block design (control and two treatments) with five replicates. Baseline data collection was undertaken in August 1998. When it became clear that the glyphosate application had been ineffective (August 1999), metsulfuron methyl (sprayed) was trialled. The 'point quadrat' method was used to determine percentage overlapping cover (referred to as cover) for all species. This involved laying a tape across each plot and dropping a steel pin down vertically every 10 cm and recording every species that the tip of the pin touched, once. This was repeated every 20 cm up the 2 × 2 m plot resulting in a total of 200 points in each plot. Measurements were taken again in August 1999 and in August 2000.

The impact of different treatments on Yellow Soldier was statistically analysed using a Kruskal–Wallis one-way analysis of variance. All other species were assigned life form categories and impacts of different treatments on these were analysed using the same test.

Our treatments

Treatments involved hand weeding and the use of two herbicides (Table 1). In

Table 1. Details of data collection and treatments of Yellow Soldier in 1998, 1999, and 2000

	August 1998	August 1999	August 2000
Contol	Baseline data collection	Data collection	Data collection
Hand removal	Baseline data collection undertaken followed by careful removal by hand of all plants	Data collection undertaken followed by the careful hand removal of all plants	Data collection undertaken
Herbicide application	Baseline data collection undertaken followed by careful wiping of all leaves of *Lachenalia reflexa* with 100 ml/L glyphosate	Data collection on effectiveness of 1998 glyphosate treatment undertaken followed by spraying with metsulfuron methyl 5g/ha (0.2g/15 L)	Data collection on effectiveness of 1999 metsulfuron methyl treatment

Box 1: Yellow Soldier: one of many exotic bulbs in southwest West Australian bushland

South African cormous and bulbous species make up one of the major weed groups in Western Australia with around 50 species from the families Hyacinthaceae and Iridaceae recorded as naturalized (Keighery 1999a). The genus *Lachenalia* is endemic to South Africa and belongs in the family Hyacinthaceae. There are around 80 named and 20 unnamed species of these bulbous perennial herbs, many of which are grown as garden ornamentals (Duncan 1988). In its native range the genus *Lachenalia* extends predominantly through the western and southwestern Cape where it occurs in winter wet rainfall areas, undergoing long dormant periods over the dry summers (Du Plessis & Duncan 1989). In recent years a number of *Lachenalia* spp. have become naturalized in southern Australia. *Lachenalia aloides* has been recorded as naturalized in lowland grassland and grassy woodland in Victoria, while *L. aloides* and *L. bulbifera* have been recorded as garden escapes in South Australia (Kloot 1987; Carr *et al*. 1992). In the southwest of Western Australia four species have been recorded as naturalized: *L. aloides*, *L. bulbifera*, *L. mutabilis* and Yellow Soldier (*L. reflexa*). Of these Yellow Soldier is considered the most widespread and invasive (Keighery 1999b).

When exactly Yellow Soldier was introduced to Perth gardens is unclear. Although a number of species of *Lachenalia* appear in Australian gardening catalogues from the 1850s onwards, no such records exist for Yellow Soldier (J. Visca and R. Randall, pers. comm., 2001). The first collection of Yellow Soldier in the Western Australian Herbarium was made in 1957 from a naturalized population at Bicton, just south of Perth. Today it occurs as a serious weed of a number of conservation reserves on sandy or calcareous soils around Perth where it appears to be replacing the herbaceous and annual components of the native understorey. Yellow Soldier has been found invading Banksia/Tuart (*Eucalyptus gomphocephala*) Woodlands and limestone scrub and heath around the Swan estuary, Banksia/Jarrah Woodland to the south and west of Perth and Tuart Woodland up to 40 km north of Perth (Keighery 1999b). At present, while the current infestations remain relatively localized, we still have an opportunity to prevent Yellow Soldier from becoming widespread in bushland throughout the southwest. It is well understood that the greatest return for effort and expenditure of money comes from controlling weeds at this early stage of invasion (Csurhes & Edwards 1998; Williams 1998).

With a single annually renewed bulb Yellow Soldier appears to spread prolifically by seed. Seed capsules contain around 60 seed and there are usually between two and 10 capsules per plant. The seed is smooth, shiny black, around 2 mm long and has an arillode on one end. Plants have also been observed to produce a prolific number of bulbils around the base of stems left lying on the soil surface but this does not appear to be a common mode of reproduction or dispersal. Fire does not appear to kill bulbs as plants flower prolifically the first season following fire (Duncan 1988; K. L. Brown, unpubl. data, 1999).

September 1998 and again in September 1999, all Yellow Soldier plants were carefully removed from designated plots (Fig. 2). This was carried out in a way that generated minimal soil disturbance (Table 1). In August 1998 when plants were in late flowering stage, each Yellow Soldier plant in each herbicide treatment plot was wiped with 360 g/L glyphosate (Roundup®; Monsanto, Melbourne, Victoria, Australia) diluted to 100 mL/L (1 : 10), using a small piece of sponge wired to a metal pin. Results the following year indicated that this had been ineffective. Given that this method proved to be time consuming and impractical for broad application, in 1999 we decided to trial spraying with a selective herbicide.

Glyphosate is inactivated by soil particles and has an estimated 10.4–26.6 days half-life on foliage (Kent & Preston 2000; Tu *et al*. 2001). It is therefore highly unlikely that by August 1999 plants in the treatment plots were still being affected by the previous year's treatment. By this time both native and introduced plants in the herbicide treatment plots, including the Yellow Soldier were observed to be green and actively growing and so were potentially receptive to a different herbicide treatment. Metsulfuron methyl (Brushoff®; Du Pont, North Sydney, NSW, Australia) was therefore spot sprayed on Yellow Soldier in each herbicide treatment plot at 5 g/ha (0.2 g/15 L) mixed with the penetrant Pulse® (Monsanto, Melbourne, Victoria, Australia) at 2 mL/L. The intention was to develop a method that was practical on a large scale. As Yellow Soldier grows closely among native vegetation, much of this also would have been sprayed.

Results of our treatments

Effect on Yellow Soldier

Baseline data collected in August 1998 and the subsequent resample in September

Figure 2. Janice Marshall, coordinator, Friends of Shenton Bushland (Inc.) carefully hand removing Yellow Soldier from the trial plots, August 1998. (Photo Kate Brown)

1999 (about 1 year after hand and glyphosate treatment) recorded no significant differences in mean percentage cover of Yellow Soldier between the control, hand removal and herbicide treatment plots. This was due to regrowth of Yellow Soldier in hand treated plots and the ineffectiveness of glyphosate in the herbicide-treated plots. Indeed, Yellow Soldier actually increased in cover from 23.2% to 28.9% in the plots treated with glyphosate prior to a significant ($P = < 0.05$) decrease to 12% cover achieved by August 2000 (1 year after metsulfuron treatment). This is a drop in cover of 65% over the period of the trial. After a follow-up treatment in the hand removal plots half way through the trial, cover had significantly dropped from a mean 27.0% in 1998 (before treatment) to 11.8% in August 2000 (Fig. 4) ($P = < 0.05$). This is a drop in cover of 43.7% over the period of the trial.

Effect on native species

Neither the drop in cover of native geophytes (Box 2) from 12.75% to 8.5% cover following application of glyphosate nor the drop from 8.5% to 7.5% cover following application of metsulfuron methyl were statistically significant (Fig. 5). There was a large variation across the trial sites in both percentage cover (which is naturally low), and in species of native geophytes. Of the eight species present only one, Milkmaid (*Burchardia congesta*), was present in all 15 plots. Leafy Sundew (*Drosera stolonifera*), Vanilla Lilly (*Sowerbaea laxiflora*), Climbing Fringe Lily (*Thysanotus manglesianus*), and *Haemadorum* spp. were present in most plots, with Pale Lily (*Caesia micrantha*) and Red Beak Orchid (*Pyrorchis nigricans*) occurring only occasionally.

Although there was a slight drop in cover in the herbicide treatment plot after glyphosate application, neither herbicide treatment had a statistically significant impact on native perennial forbs (Box 2) at the trial site. Overall cover increased in all plots over the 2 years (Fig. 6). Mat Rushes (*Lomandra* spp.), Prickly Conostylis (*Conostylis aculeata*), *Tetraria octandra, Alexgeorgia nitens* and *Mesomelaena pseudostygia* were the most common perennial forbs. A similar effect occurred in terms of the cover of native shrubs. There was an overall increase in all plots but cover dropped off slightly in the herbicide treatment plots following the metsulfuron methyl application The commonly occurring shrubs included Hairy Yellow Pea (*Gompholobium tomentosum*), *Daviesia nudiflora* and Grass Tree (*Xanthorrhoea preissii*). Little or no germination of shrubs was observed or recorded and any increase in cover was largely provided by existing vegetation.

Effect on other introduced species

Cover of introduced annual forbs increased in all plots, especially in the hand-treated

Box 2: The herb layer of a Banksia Woodland

Figure 3. Exotic bulb, Yellow Soldier (*Lachenalia reflexa*), flowering in the understory of the banksia woodland at Shenton Bushland, WA. (Photo: Kate Brown)

The herb layer of the Banksia Woodland is very species rich with a diverse range of geophytes, perennial and annual forbes and some scattered grasses. In southwest Western Australia geophytes die back to an underground storage organ such as a bulb, tuber, rhizome or corm over summer resprouting in as the days shorten and the rains start in autumn. The common geophytes in Shenton Bushland include Milkmaids (*Burchardia congesta*), Vanilla Lily (*Sowerbaea laxiflora*), Fringe Lily (*Thysanotus manglesianus*), Leafy Sundew (*Drosera stolonifera*), Pale Grass Lily (*Caesia micrantha*) and *Haemadorum* spp. Many species of perennial forbs are also present. These include a number of species of Mat Rush (*Lomandra* spp.), Prickly Conostylis (*Conostylis aculeata*), *Tetraria octandra*, *Mesomelaena pseudostygia* and Yellow Autumn Lily (*Trichoryne elatior*). Commonly occurring annual forbs include Slender Podolepis (*Podolepis gracilis*), *Lagenophora hueglii* and *Centrolepis drummondiana*. Native grasses are generally uncommon, however, immediately following fire the annual *Austrostipa compressa* is a feature in the understorey, flowering and growing prolifically.

In recent times a range of exotic herbs have started to invade the woodland displacing the native understorey. These include exotic geophytes such as Yellow Soldier, Guilford Grass (*Romulea rosea*, Freesia (*Freesia alba* × *leichtlinii*), Watsonia (*Watsonia meriana*) and Black Flag (*Ferraria crispa*). Geraldton Carnation Weed (*Euphorbia terricina*) and Rose Pelagonium (*Pelagonium capitatum*) both perennial forbs, are serious invaders and many exotic annual forbs are common, particularly in the highly disturbed areas. These include Flat Weed (*Hypochaeris glabra*), Ursinia (*Ursinia anthemoides*), French Catchfly (*Silene galica*), and Slender Suckling Clover (*Trifolium dubium*). Perennial Veld Grass (*Ehrharta calycina*) is one of the most serious invaders of these woodlands often moving into previously intact areas following fire.

plots. By far the most common of these was Flat Weed (*Hypochaeris glabra*) but other species such as Ursinia (*Ursinia anthemoides*), and French Catchfly (*Silene galica*) also occurred. In August 1998 the cover of introduced annual forbs in all plots was between 5 and 9%. By August 2000 introduced annual forb cover in the hand removal plots was 34% while in the control and herbicide treatments it made up 19% and 17% cover, respectively. Although the increase in cover of these weedy annual forbs in the hand removal plots was very high compared to that of the other treatments, the difference between the means was not found to be statistically significant due to high variance (Fig. 7). While stems were not counted it was clear that the increase in cover of annual forbs was mainly due to an increase in germinants particularly of Flat Weed.

The cover of Guilford Grass (*Romulea rosea*) was greatly reduced following the application of metsulfuron methyl. Cover of introduced Perennial Veld Grass increased from between 9% and 13% to

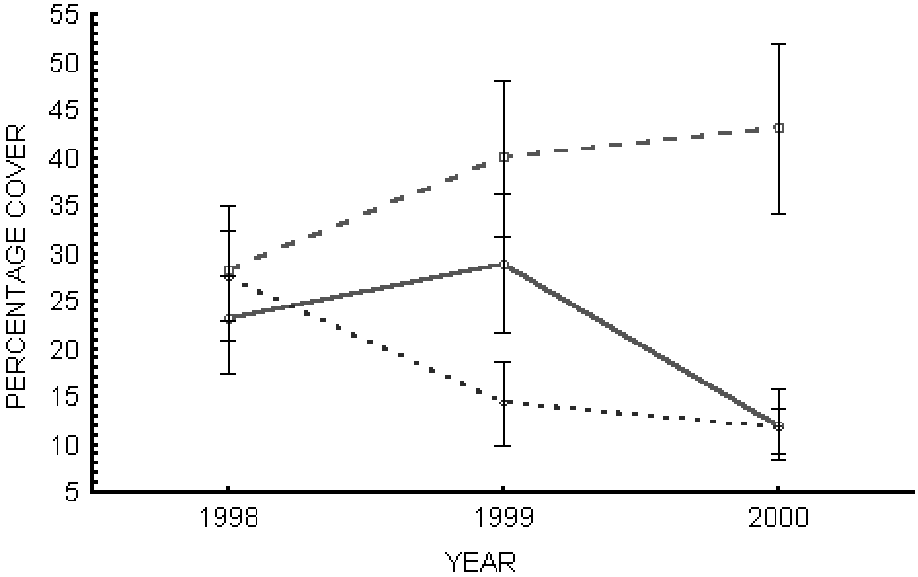

Figure 4. Mean per cent cover of *Lachenalia reflexa* in control (squares and dashed line), hand removal (diamonds and dotted line) and herbicide (circles and solid line) treatment plots in 1998 (pre-treatment) 1999 and 2000. The bars indicate standard errors.

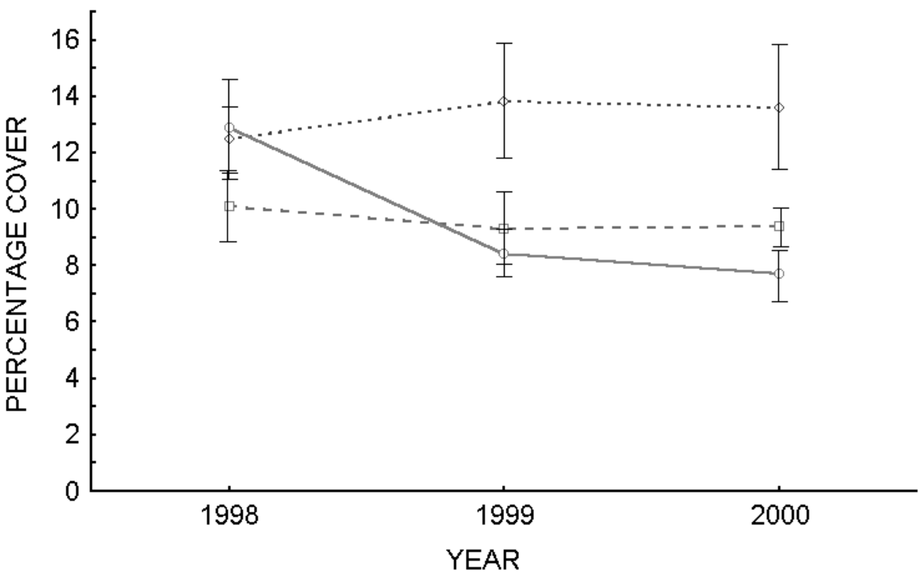

Figure 5. Mean per cent cover of native geophytes in control (squares and dashed line), hand removal (diamonds and dotted line) and herbicide (circles and solid line) treatment plots in 1998 (pre-treatment) 1999 and 2000. The bars indicate standard error.

between 23% and 25% in all plots from 1998 to 1999. Following the broad scale application of Fusilade® across the bushland in 1999, the cover in all plots had dropped to zero by August 2000.

Bare ground

The percentage of bare ground dropped in all plots over 1998/1999, levelling out in the control and hand removal plots over 1999/2000. The cover of bare ground in the herbicide treatment plots, however, rose significantly over 1999/2000 (Fig. 8) ($P < 0.01$).

Discussion

Although hand removal was effective in significantly reducing the cover of Yellow Soldier by the second year of treatment, it proved an impractical method of control. Each 2 m × 2 m plot took around 4 h for one person to hand weed in the first year; with up to 1700 bulbs in the pre-treatment plots (K. Brown, unpubl. data, 1998). By the second year it still took 2 h to hand remove Yellow Soldier from each plot. There is also strong evidence that soil disturbance led to the increase in weedy annual forb cover. The initial increase in cover of annual weedy forbs that occurred across all plots was probably a reflection of conditions following the October 1997 fire. The cover of these weedy annual forbs levelled off in both the herbicide treatment and control treatment plots over 1999/00 but continued to increase in the hand weeded plots. A number of studies have documented the association between annuals and soil disturbance (Grime 1979; Hobbs & Atkins 1988; McIntyre *et al.* 1995). Soil disturbance opens up space and favours taxa that are able to disperse effectively and rapidly exploit resources. Flat Weed, with its wind dispersed seed and flat rosette of leaves is a prime example. Any hand removal program aimed at controlling bulbous weeds such as Yellow Soldier, needs to take into consideration the likelihood that colonization of annual weeds will result.

Glyphosate is a non-selective herbicide and would have been expected to kill Yellow Soldier at the rates applied. Its lack of effect may have been due to treatment during the plant's late growth stage (late flowering) or perhaps a poor coverage when compared to a spray application. Also, glyphosate is inactivated by soil particles (Parson 1995; Kent & Preston 2000). Applying the herbicide to individual plants growing close to the ground meant that the herbicide applicator was easily contaminated by soil particles and this could have contributed to the failure of this treatment. Applying high rates of glyphosate with modified wick applicators has been found to be a highly successful method of controlling Watsonia (Day 1993). However, this method was found to be impractical for Yellow Soldier due to the habit and small size of the plants (up to 20 cm) and the densities at which they occurred (up to 450 plants in 1 m^2).

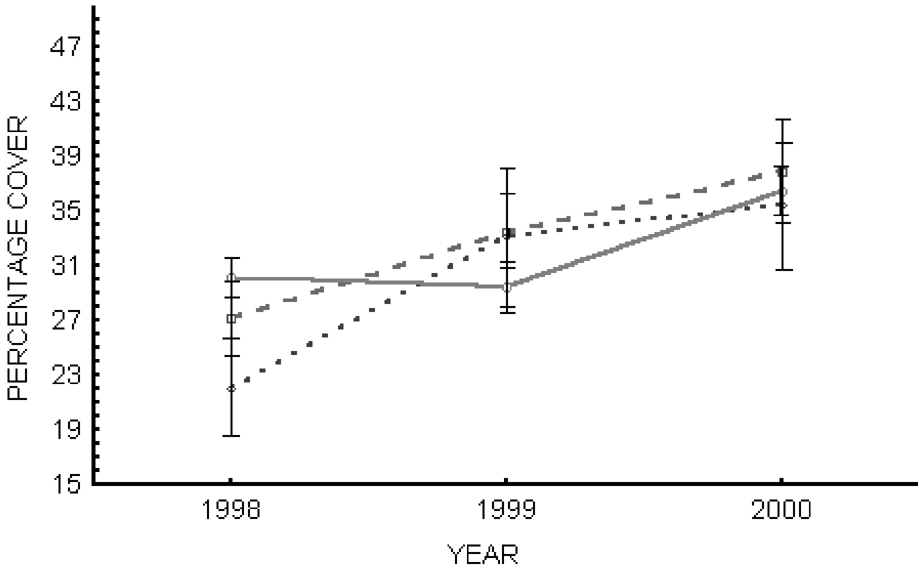

Figure 6. Mean per cent cover of native perennial forbs in control (squares and dashed line), hand removal (diamonds and dotted line) and herbicide (circles and solid line) treatment plots in 1998 (pre-treatment) 1999 and 2000. The bars indicate standard error.

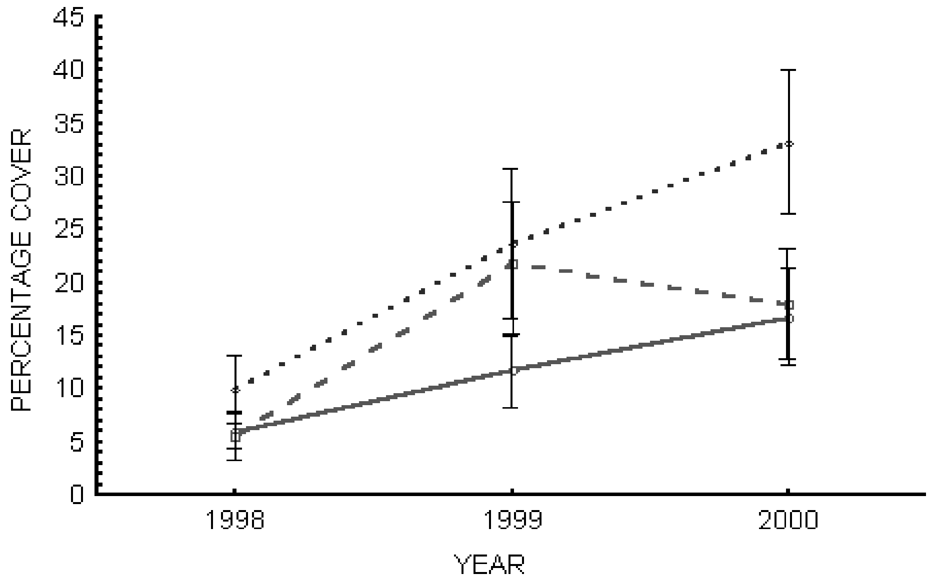

Figure 7. Mean percent cover of weedy annuals in control (squares and dashed line), hand removal (diamonds and dotted line) and herbicide (circles and solid line) treatment plots in 1998 (pre-treatment) 1999 and 2000. The bars indicate standard error.

Although there was a drop in cover of perennial forbs and native geophytes following application of glyphosate to Yellow Soldier, these drops were relatively small and not statistically significant. There was no obvious mortality in the native perennial forbs and they were actively growing the year following application of glyphosate to the Yellow Soldier. Mortality of native geophytes is more difficult to assess as all plants die back each year anyway. The results could also have been compounded by the fact that some native geophytes such as Red Beak Orchid often grow and flower prolifically immediately after fire dropping back in the years following (Pate & Dixon 1982). Certainly it is unlikely that glyphosate wiped carefully on the leaves of Yellow Soldier affected other species in the treatment plots.

Implications for management

Metsulfuron methyl at 5 g/ha (0.2 g/15 L) with Pulse® was clearly the more effective of the two herbicide treatments, significantly reducing the cover of Yellow Soldier by more than 65% in one year while having no significant impact on the native flora. The group of native plants we would most expect to be affected, the native geophytes, were reduced by only 1% following spraying of metsulfuron methyl in the treatment plots. However, given the naturally low cover and variation in species of native geophytes across all plots, it is difficult to draw conclusions from these trials. The impacts of metsulfuron methyl on our native geophytes is an area that requires further research.

The implementation of these results on a broad scale therefore needs to be undertaken with caution. In this trial, the herbicide was, where possible, targeted at Yellow Soldier and not applied as a blanket treatment over all vegetation. This is not a difficult or time consuming task but does require responsible operators with a reasonable knowledge of the flora. In addition there is evidence from other studies that some native species are susceptible to metsulfuron methyl at 5 g/ha. Moore (1999) found that five out of 39 species of Western Australian native tree and shrub seedlings growing in pots under glasshouse conditions had growth or survival reduced by more than 50% after metsulfuron methyl (5 g/ha) treatment; and a further 13 required more research.

Another concern is that metsulfuron methyl can remain active in dry alkaline soils and is absorbed by roots for many months following application (Parsons 1995; Noy 1996). Its use in native vegetation therefore requires very careful application and monitoring.

Need for follow up

Yellow Soldier still made up 12% cover in 2000 indicating that any broad scale application would need to be carefully followed up for a number of years following initial application to ensure reinvasion did not occur. The changes in the cover of different components of the vegetation, as

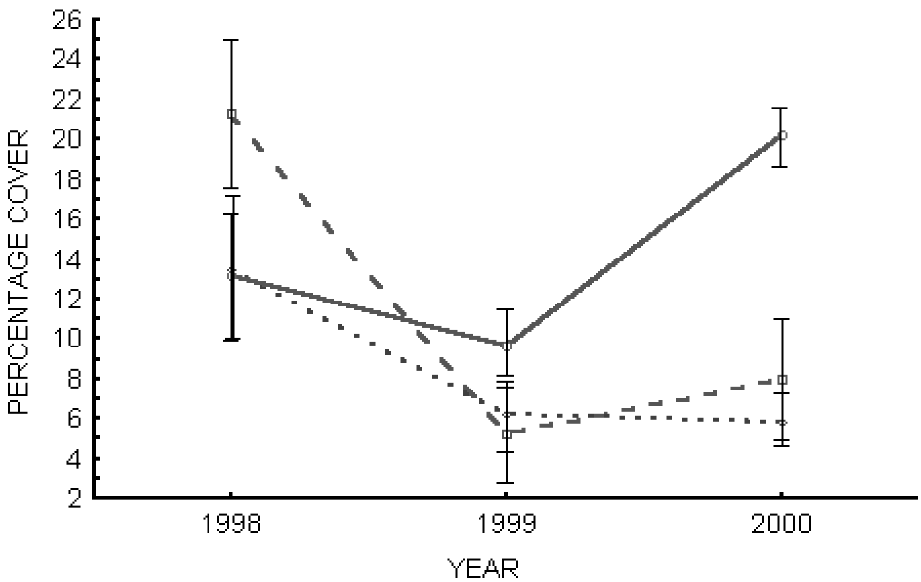

Figure 8. **Mean per cent cover of bare ground in control (squares and dashed line), hand removal (diamonds and dotted line) and herbicide (circles and solid line) treatment plots in 1998 (pre-treatment) 1999 and 2000. The bars indicate standard error.**

Yellow Soldier is removed, will also need to be carefully monitored. In the species-rich Banksia Woodland at Shenton Bushland, Yellow Soldier co-occurs with up to 25 native species in a 4 m × 4 m quadrat and the current policy is to allow indigenous species to recolonize unassisted. Results from the present study, although only preliminary, indicate that there will not be an increase in any introduced species following herbicide control of Yellow Soldier in Shenton Bushland. However, the significantly high cover of bare ground in the herbicide-treated plots indicates that the site will need to be carefully monitored. One of the major contenders for invading sites where bulbous weed control has taken place on the sandy soils of the Swan Coastal Plain is Perennial Veld Grass. The Fusilade® spray program has successfully controlled this weed over much of Shenton Bushland including the study site.

Addressing causes

As well as establishing appropriate control methods, any successful management strategy for an individual weed species needs to address the factors that led to the introduction and spread of that species in the first place. As Yellow Soldier was grown as a garden ornamental it can only be assumed that it spread from garden refuse dumped in the bushland. Often, with weed invasion into bushland, there is a clear association with disturbance (Fox & Fox 1986; Hobbs & Atkins 1988; Hester & Hobbs 1992; Morgan 1998; Buist *et al.* 2000). However, distribution of Yellow Soldier in Shenton Bushland does not necessarily follow disturbance with populations extending into relatively intact bushland.

Interestingly, the populations are generally quite discrete suggesting that the seed is not dispersed over very long distances. Holmes and Cowling (1997) found that most seed-reproducing geophytes occurring in the shrublands of southern Africa relied on passive dispersal; and water is possibly playing a role in its spread within Shenton Bushland. Fire also possibly plays a role in spreading Yellow Soldier within the bushland, reducing competition from the native vegetation and creating bare areas where the seeds can germinate. Certainly the increase in the cover of Yellow Soldier in the control plots over the 2 years following fire, was substantial.

As well as possibly facilitating the spread, fire can also create opportunities for control of Yellow Soldier. A hot fire can often destroy seed in the litter layer and top 5 cm of soil (Floyd 1966; Whelan 1995; Fisher 1998) and Dixon (1998) noted the destruction of Freesia seed following very hot fire in Kings Park bushland. In addition, after fire the plants are clearly visible and the reduced cover of native vegetation makes the resprouting flowering bulbs an easy target for herbicide control.

Possibilities for the future

With the presence of an active Friends group, dumping of garden refuse rarely occurs in Shenton Bushland any more. As Yellow Soldier is rarely used by contemporary gardeners and is no longer grown or sold in Western Australia, once it is eradicated from the bushland it is improbable that it will be reintroduced. Furthermore as the seed does not appear to be dispersed over long distances, it is unlikely to be introduced from other reserves. It is therefore well worth putting resources into eradicating it from the bushland using consistent programs of control such as the one described here. With Yellow Soldier still having a relatively localized distribution within the State, it is also worth considering putting resources into eradicating it from other bushland in southwest Western Australia.

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