

Yellow soldier

Lachenalia reflexa

Draft strategic control plan for the Swan NRM Region

December 2009



ACRONYMS

DEC – Department of Environment and Conservation
DAFWA – Department of Agriculture and Food Western Australia
SCC – Swan Catchment Council
LGA – Local Government Authority
NRM – Natural Resource Management
IBRA – Interim Biogeographic Regionalisation of Australia

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FOREWORD

Valued in some parts of the world as an ornamental, the South-African yellow soldier or *Lachenalia reflexa* is a significant environmental weed in Western Australia. With its impacts on biodiversity and potential for rapid spread, it is listed as a National Environmental Alert Weed (Weeds CRC 2003). Western Australia currently has the only known occurrences of the weed in Australia and all of these populations are restricted to the Swan Natural Resource Management (NRM) Region.

Yellow soldier has the potential to spread throughout the south-west corner of the State, as well as increase in abundance in its current range. It is able to severely impact on native flora, fauna and plant communities of the areas it invades. This may have major implications for areas of the south-western corner of Western Australia, which is considered amongst the world's 34 plant biodiversity hotspots.

Management of yellow soldier presents major challenges. While some infestations are small and localised and therefore can be eradicated, many are well-established and threaten sites with high biodiversity values such as regionally significant bushland and areas containing rare or restricted species. Currently in Western Australia it is not declared or listed as a pest plant, there is no legal requirement for infestations to be eradicated. Once established in bushland, yellow soldier is difficult to control. As with many other weeds, it occurs across a range of tenures, making communication, coordination and cooperation integral in implementing an effective management program.

The aim of this strategy is to coordinate and implement on-ground actions to control infestations of yellow soldier which threaten high biodiversity assets. The strategy provides the following information on yellow soldier:

- biology and ecology
- current and potential extent in Australia, Western Australia and the Swan NRM Region
- impacts and threats
- best practice control methods
- management.

The purpose of this strategy is to:

- provide baseline information essential to the strategic control of yellow soldier in the Swan NRM Region
- facilitate, encourage and provide support to regional and local control efforts
- raise awareness among land managers and the public.

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1. CONTEXT AND PREPARATION

This strategy has been developed as an outcome of a Natural Heritage Trust-funded Invasive Environmental Weed Project for the Swan NRM Region. The project forms part of the 2006-2008 Swan Catchment Council (SCC) Investment Plan, which is being completed by the Department of Environment and Conservation (DEC). Among the project's outcomes is the development of strategic plans for six of the region's high priority environmental weeds, one of these being yellow soldier. Each of the species presents a major threat to the region's rich biodiversity values. The six species were selected to represent a range of life forms and different management objectives and approaches, so the plans could be used as models to develop strategies for other environmental weeds in the region and beyond.

2. AREA COVERED

This strategy centres on the Swan NRM Region in the south-west of Western Australia. It is made up of the Swan Coastal Plain and Jarrah Forest Interim Biogeographic Regionalisation of Australia (IBRA) regions and numerous, overlapping management boundaries. These include NRM sub-regions, DEC regions and districts and Local Government Authority (LGA) boundaries, as shown in Figure 1.

3. DESCRIPTION

Taxonomic relationships

Yellow soldier belongs to the genus *Lachenalia* in the family Hyacinthaceae. This is a large family made up of around 850 species of deciduous or rarely evergreen bulbous geophytes. Most species are found in the northern hemisphere but they can also occur in southern Africa (Duncan 2003). The genus *Lachenalia* has been placed in the subfamily *Hyacinthoidea* and *Massoniense* tribe, and has also been placed in the family Liliaceae. The genus is made up of about 120 species of deciduous bulbous geophytes endemic to southern Africa (United States Department of Agriculture 2000).

Known generically as 'cape cowslips', *Lachenalia* occur in a variety of habitats and vegetation types, from near sea level to altitudes greater than 2,000 metres. Their distribution extends from south-western Namibia across the western, central, southern and south-eastern parts of South Africa. They are concentrated in winter rainfall zones, but also extend into intermediate and summer rainfall areas (Duncan 2003). Many species are adapted to seasonal climates that have a pronounced dry or cold period and several species are adapted to grow in coastal sands in reach of the sea spray (Manning 2004).

Lachenalia have several key features which make them readily identifiable at certain times of year. They have two opposite leaves, are annually renewed and flower between June and September. In the genus, there is much variation in flower colour, shape and size, with this variation making *Lachenalia* an ideal subject for hybridization (Duncan and Linder Smith 1999).

Yellow soldier features

Yellow soldier is a bulbaceous geophyte 0.05 to 0.25 m high. It has two lanceolate or strap-shaped leaves 60 to 350mm long and 15 to 25mm wide which grow upward from the base, and are slightly v-shaped in cross section. Yellow flowers borne from July to August are 25mm long and more or less tubular in shape and swollen in the centre. They grow on short stalks or stems 45 to 100mm above the ground that are upturned rather than drooping (Weeds CRC 2003). Unlike most *Lachenalia*, the flowers of yellow soldier are born upright on a peduncle that pushes the flowers just above the foliage (Pacific Bulb Society 2007).

The fruit of yellow soldier is a non-fleshy, dry, dehiscent, loculicidal capsule that splits along three sides to release the seeds. There can be over 12 fruits developed per inflorescence or plant, with 20 to 100

seeds per fruit (Macfarlane *et al* 2000). The seed are small (1.5mm), glossy black and roughly circular with an aril at one end.



Figure 2: From left to right; form of yellow soldier; scanned entire flowering plant; seed and fruit; new bulb and cross section of single flower, mass of stems (Photos: K.Bettink).

Similar species - native and exotic

Yellow soldier is unlikely to be confused with many native species but may be superficially similar when vegetative to some co-occurring Orchidaceae, such as *Diuris* or *Caladenia* species. Three other species of *Lachenalia* are naturalised in south-west Western Australia (WA Herbarium 2008) (Figure 3). Yellow soldier is the most common and widespread *Lachenalia* in the region and is considered the most widespread and invasive of all the *Lachenalia* species known in Australia (Weeds CRC 2003).

All naturalised *Lachenalia* flower in winter and early spring. Spotted soldier (*L. aloides*) has tricoloured flowers of orange, green and purple-brown, is the mostly widely planted and is occasionally found naturalised throughout the south-west of WA. Red soldier (*L. bulbifera*) is robust, red-flowering and can produce numerous small bulbils along the stems. *L. mutabilis* is less common and has pale blue flowers on opening which turn crimson brown with age (Hussey *et al* 2007).

4. HISTORY OF INTRODUCTION AND SPREAD

Yellow soldier was first recorded naturalised south of Perth in 1957, most likely after escaping from gardens or from material accidentally or deliberately transferred into bushland. Various *Lachenalia* species have been offered for sale in nurseries around Australia, including Western Australia, South Australia and Victoria (Weeds CRC 2003), however, no records indicate that yellow soldier was ever sold in nurseries. Its introduction and later spread may have largely been through private trade or spreading of contaminated soil and garden waste. The movement of material outside gardens across the metropolitan area has allowed yellow soldier to occupy a significant range from the northern to southern coastal plain of Perth.

5. HABITAT AND DISTRIBUTION

Native range

Yellow soldier originates in the Cape Floristic Region of South Africa where it grows on wet sandy flats in the south-western cape (Pacific Bulb Society 2007). It extends mainly through the western and south-western Cape Province in winter rainfall areas where it undergoes long dormant periods over the dry summers (Weeds CRC 2003).

Australia and Western Australia

At present there are no records of yellow soldier naturalised in other states outside of Western Australia (Australian Virtual Herbarium 2008). Herbarium collections made over past decades have given an indication the basic distribution of yellow soldier where it occurs in Western Australia (Figure 4.1) (WA Herbarium 2007). Modeling using Climate[®] software and Climex[®] modeling undertaken by Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Figure 5) has shown that yellow soldier could potentially further extend its range to occupy coastal areas of southern Western Australia (Scott *et al* 2008).

As a result of recent survey effort and responses from the public and land managers in the region, a total of 31 populations have been identified, with all known populations found in the Swan NRM Region of south-west of Western Australia (Figure 4.2). These populations occur on the Swan Coastal Plain extending 40km south and 35km north of the Perth CBD. They occur in three general areas in the region: in large, well established populations in the Woodvale/Craigie/Kinglsey area north of Perth, in the Como/Melville/Cockburn/Fremantle/Shenton Park areas, and then a satellite population further south near Rockingham. Details of all populations are given in Table 1 (overleaf).

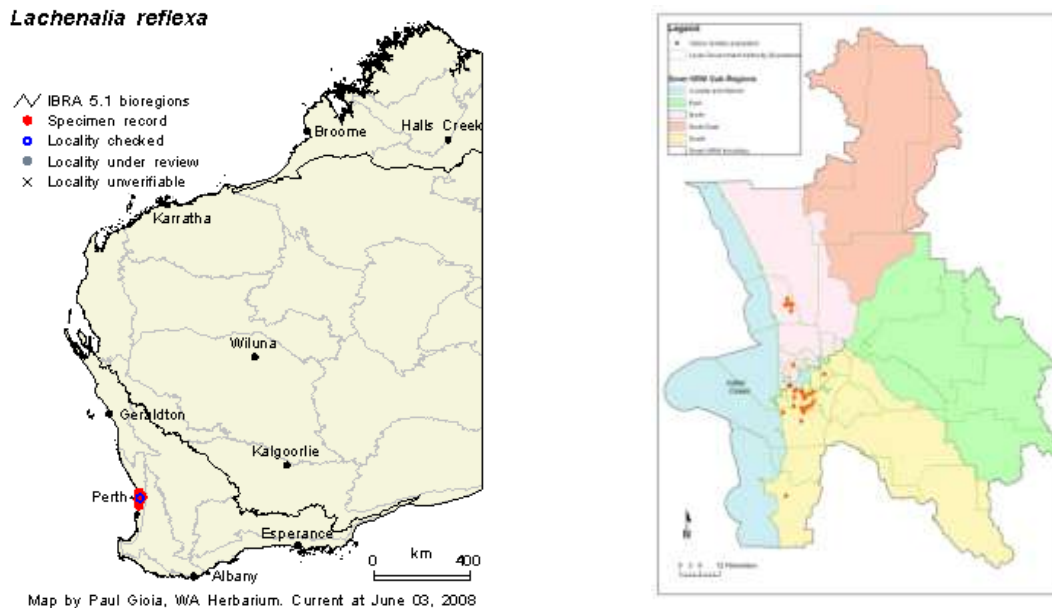


Figure 4.1: (left) Current distribution of yellow soldier in Western Australia based on WA Herbarium records (Western Australian Herbarium 2007); **4.2 (right)** distribution in the Swan NRM Region.

Almost all known populations occur in bushland reserves, many with significant conservation values, on the Swan Coastal Plain. Of the 31 known populations, 18 occur in regionally significant bushland (Bush Forever sites) listed in Table 2. Ten populations occur in other bushland reserves and three were found in highly modified sites.

Table 2: Bush Forever sites invaded by yellow soldier.

Mt Henry Peninsula Bushland	Sir Frederick Samson Park
Bibra Lakes	Minim Cove
Lake Cooloongup	Blackwall Reach Reserve
Little Rush Lakes	North Lake
Shenton Bushland	Piney Lakes Reserve
Woodvale Nature Reserve	Shepards Bush Park
Manning Lake	Wireless Hill
Blue Gum Lake	Point Heathcote
Harry Sandon Park	Alfred Cove

Table 1: Table of yellow soldier sites in the region as of September 2008.

Population no.	Location description	Suburb	Approx area infested (ha)	Managing agency	Listed biodiversity assets/Other special attributes	Listed biodiversity assets in close proximity (0- <1km)	Active friends group/other	Rating - Biodiversity assets	Feasibility of control	Threat- adjacent/close proximity biodiversity assets	Outlying population Y/N	Score	Overall rating	History of <i>L. reflexa</i> management	Management recommendations - short term 2008/2009	Management aim - short term	Management recommendations - medium term 2009-2012	Management aim - medium term	Management recommendations - long term 2012 - 2020+	Management aim - longer term
15	Mt Henry Peninsula	Como	2	Aquinas College/Mt Henry Peninsula Conservation Group	Bush Forever site (BFS) 227, significant bird species, significant flora, ecological linkage, Other special attributes, Listed EPBC Act 1999, Entered in the Register of the National Estate	Adjacent to BFS 333 (Canning River Foreshore, Salter Point o Wilson), remnant vegetation	Mt Henry Peninsula Conservation Group	1	2		N	4	V H	Mapped 2006. Herbicide treated and outlying plants removed in consecutive years since at least 2004. Monitoring program established 2006.	Continue herbicide treatment. Monitor July/August	Significantly reduce density and extent of infestation	Remap, remonitor, continue herbicide spraying program.		Continue treatment, evaluate program and progress toward eradication	Eradication by 2011
17	Bibra Lakes	Bibra Lake	3	City of Cockburn	BFS 244, significant flora, significant bird and mammal species, listed EPBC Act 1999, Interim List of the Register of National Estate, Ecological linkage	Remainder of BFS 244 (North Lake), remnant vegetation, 0.1km to BFS 254, Beeliar Regional Park (south)		1	2	1	N	4	V H	None	Continue monitoring and spraying program. Remap in August		Continue monitoring and spraying program. Remap in August		Continue monitoring and spraying program. Remap in August	Long term management required
20	Lake Cooloongup RP	Cooloongup	>1	Regional Parks	BFS 356, significant flora and fauna, ecological linkage	Lake Walyungup and adjacent bushland, Hillman to Port Kennedy	Friends of Rockingham Lakes Regional Park	1	1	1	Y	3	V H	Mapped 2006. Monitoring established 2006. Herbicide treated 2006-07	Continue herbicide treatment. Monitor July/August. Maintain surveillance in remainder of Reserve.	Significantly reduce density and extent of infestation	Continue herbicide treatment. Monitor July/August. Maintain surveillance in remainder of Reserve.	Eradicate	Maintain surveillance	Ensure no reintroduction/establishment
32	Little Rush Lakes	Yangebup	0.01	City of Cockburn	BFS 256, significant flora, significant bird and mammal species, Ecological linkage, Interim List of the Register of National Estate, location for JAMBA/CAMBA species	Beeliar Regional Park (south)		1	1	1	Y/N	3	V H	None	Continue hand removal & spraying program		Recheck. Maintain surveillance		Recheck. Maintain surveillance	Eradication by 2009
3	Shenton Bushland	Shenton Park	3	City of Nedlands	BFS 218, significant flora, significant bird and reptile spp., Ecological linkage, National Trust of Australia (WA), Classification	Remnant Bushland, Bold Park	Friends of Shenton Bushland	1	2	2	N	5	H	Mapped 2004? Herbicide treated consecutive years. Monitoring in place.	Monitor and undertake herbicide spraying July-August	Reduce density and extent of infestation	Monitor population. Survey for new infestations within Reserve. Continue herbicide spraying program.		Monitor	Eradicate. Ensure no reintroduction
11	Woodvale Nature Reserve	Woodvale	30+	DEC	BFS 407, significant flora, significant reptile and mammal species, part of regionally significant bushland wetland linkage	Adjacent bushland to west (BFS 303), across freeway, Yellagonga Regional Park 500m to east		1	3	1	N	5	H	Some past control & mapping	Develop map and priority control areas. Continue herbicide treatment. Monitor July/August		Continue herbicide treatment. Monitor July/August		Continue herbicide treatment. Monitor July/August	Long term management required
19	Harry Sandon Park	Melville	1	City of Melville	BFS 226, significant flora, significant bird species	BFS 337, P4 spp		1.5	2	2	N	5.5	H	Some past control?	Continue herbicide spraying program.					Eradicate by 2011
22	Manning Lake	Hamilton Hill	1	City of Cockburn	BFS 247, significant flora, significant bird species, ecological linkage, Interim list of the Register of the National Estate	Remnant vegetation, including adjacent bushland Hamilton Hill/Spearwood		1.5	1	2	N	4.5	H	None	Check, assess for spraying. Treat as required.		Recheck, treat as required. Check proximity		Monitor	Eradicate by 2010

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27	Dudley Hartree Park	Leeming	0.1	City of Melville	Remnant vegetation	Remnant vegetation with DRF 0.6 km to north west & 1km to south		2.5	1	2	N	5.5	M / H	None	Continue herbicide spraying program.		Recheck, treat as required. Check proximity			Eradicate by 2011
2	Blue Gum Lake	Booragoon	>1	City of Melville	BFS 228, Register of National Estate, location for JAMBA/CAMBA species, significant bird species	BFS337	Friends of Blue Gum Lake	2	2	2	N	6	M	Mapped 2004? Herbicide treated 2007	Continue herbicide spraying program.		Re-map and continue herbicide spraying program as required.		Check, treat as required	Eradicate by 2011
4	Point Heathcote	Applecross	>1	City of Melville	BFS 329, National Trust of Australia (WA) Classification, significant bird and reptile species, significant flora, Ecological linkages	None		2	2	3	N	7	M	None	Check, assess for spraying.		Check, treat as required			Eradicate by 2011
5	Wireless Hill	Ardross	3+	City of Melville	BFS 336, significant flora, National Trust of Australia (WA) Classification	None	Friends of Wireless Hill	1	3	3	N	7	M	Mapped in 2005. Some isolated herbicide spraying	Monitor. Continue herbicide spraying program.		Remap & continue herbicide spraying program as required.			Long term management required
6	Sir Frederick Samson Park	Samson	10	City of Fremantle	BFS 59, significant bird species	None		2	3	3	N	8	M	Some isolated herbicide spraying	Continue herbicide treatment. Monitor July/August					Long term management required
7	Minim Cove	Sth Fremantle	>0.5	Town of Mosman Park	BFS 335, significant flora	Chidley Pt and adjacent bushland BFS 334		2	2	2	N	8	M	None	Check, assess for spraying.		Recheck, treat as required. Check proximity		Check, treat as required	
8	500m West Lemnos Hospital	Shenton Park	0.1	City of Nedlands	None - disturbed	Shenton Park bushland		3	2	2	N	7	M	None	Check, assess for spraying.					
9	Blackwall Reach Reserve	East Fremantle	3+	City of Melville	BFS 331, significant flora and fauna, location for JAMBA/CAMBA species, Entered on the Register of the National Estate	Point walter, Adjacent bushland, Bicton to Applecross		2	3	2	N	7	M	Mapped in 2005. Broadly rechecked 2007 (DEC)	Continue herbicide spraying program.		Continue herbicide spraying program.		Continue herbicide spraying program	
12	Alfred Cove, south bank	Attadale	>1	City of Melville	BFS 331, significant flora and fauna, location for JAMBA/CAMBA species, National Trust of Australia (WA) Classification	Point walter, Adjacent bushland, Bicton to Applecross		2	2	2	N	6	M	None	Continue herbicide spraying program. Remap August.		Recheck, treat as required. Check proximity		Check, treat as required	
16	Craigie Bushland (open space)	Criagie	20+	City of Joondalup	Remnant vegetation	Remnant vegetation		2	3	3	N	8	M	Some isolated herbicide spraying	Continue herbicide spraying program.		Continue herbicide spraying program.		Continue herbicide spraying program.	Long term management required
18	Murdoch TAFE	Murdoch	3	TAFE	Remnant vegetation/disturbed	None		2.5	2	2	N	6.5	M	Mapped 2006	Recheck and assess.		Recheck and assess.		Recheck and assess.	Unsure land status
21	North Lake Regional Park	North Lake	10	Regional Parks	BFS 244, significant flora, significant bird and mammal species, entered in Interim List of the Register of National Estate, Ecological linkage	Remainder of BFS 244 (Bibra Lake), remnant vegetation		1.5	3	2	N	6.5	M	Some isolated herbicide spraying	Continue herbicide spraying program. Remap August.		Remap and continue herbicide spraying program as required.		Continue herbicide spraying program	Long term management required

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26	Harry Stickland Reserve	Booragoon	0.2	City of Melville	Remnant vegetation	Remnant vegetation		2.5	2	2.5	N	6. 5	M	None	Continue herbicide spraying program.		Continue herbicide spraying program.		Check, treat as required	
28	Chichester Park	Woodvale	5+	City of Joondalup	Remnant vegetation	Yellagonga Regional Park		2.5	2	2	N	6. 5	M	None	Continue herbicide spraying program.		Continue herbicide spraying program		Continue herbicide spraying program	Long term management required
1	Murdoch Uni bushland	Murdoch	1+	Murdoch University	Remnant vegetation, significant flora	Remnant vegeation, BFS202		2.5	2	2	N	6. 5	M / L	Mapped (DEC) 2006	Liaise with University. Survey and map July, Undertake herbicide spraying July-August.		Continue herbicide spraying program.		Check, treat as required	
23	Wal Hughes Reserve	Attadale	0.8	City of Melville	Remnant vegetation	0.4 km BFS 226		2.5	2	2.5	N	7	M / L	Mapped in 2005.	Continue herbicide spraying program.		Continue herbicide spraying program.		Check, treat as required	
24	Olding Park	Melville	0.2	City of Melville	Remnant vegetation	None	Yes	2.5	2	3	N	7. 5	M / L	Mapped in 2005.	Continue herbicide spraying program.		Continue herbicide spraying program.		Continue herbicide spraying program	
25	Piney Lakes Reserve	Winthrop	6	City of Melville	BFS 339, significant fauna and flora, Interim list of the Register of the National Estate	BFS 337 0.05km to north east		2	3	2	N	7	M / L	Some isolated herbicide spraying. Mapped in 2005.	Monitor. Continue herbicide spraying program.		Remap & continue herbicide spraying program as required.		Continue herbicide spraying program	Long term management required
29	Shepards Bush Park	Kingsley	5+	City of Joondalup	BFS 39	None		2	3	3	N	8	M / L	Some isolated herbicide spraying	Continue herbicide spraying program.		Continue herbicide spraying program.		Continue herbicide spraying program	Long term management required
30	Timberlane Park	Woodvale	2	City of Joondalup	Remnant vegetation/disturbed	Yellagonga Regional Park		2.5	3	2	N	7. 5	M / L	None.	Monitor. Continue herbicide spraying program.		Monitor. Continue herbicide spraying program.		Monitor. Continue herbicide spraying program	Long term management required
31	Fred Johnson	Bullcreek	0.2	City of Melville	Remnant vegetation	None		2.5	2	3	N	7. 5	M / L	None	Continue herbicide spraying program.		Continue herbicide spraying program.		Check, treat as required	Eradicate by 2011
10	Sump, Carlisle Rail Station	East Vic Park	>1	Town of Victoria Park/Water Corporation	None - disturbed	None		3	3	3	Y	9	L	None except for mowing?	Herbicide spray (blanket)		Follow-up herbicide spray (blanket)		Check, treat as required	eradication

Most commonly yellow soldier is found on Quindalup and Spearwood dune associations, characterised by grey, white or yellow calcareous sands. Plant communities of these soils readily invaded by yellow soldier include tuart (*Eucalyptus gomphocephala*)/ marri (*E. calophylla*)/Jarrah (*E. marginata*) and banksia (*Banksia menziesii*, *B. attenuata*) woodland with herbaceous understorey (Figure 6). Coastal heath and shrubland on the extreme western portion of the region is also susceptible to invasion. These communities are typified by parrot bush (*Dryandra sessilis*), *Jacksonia furcellata*, *Melaleuca systena* and coastal wattle (*Acacia cyllops*). Yellow soldier can be found in these areas in densities up to 1,500 plants per square metre.

6. BIOLOGY, ECOLOGY AND THREATS

Yellow soldier is well-adapted to survive the pronounced dry and cold periods of the seasonal climate in South Africa and the Mediterranean climate of south-west Western Australia. It does so by losing the above ground leaves and stems and the bulb entering dormancy during late spring and summer (Duncan and Linder Smith 1999). Upon flowering the old bulb is exhausted and another new bulb is formed, illustrated in Figure 7.

With the onset of Autumn rain the dormant bulbs grow rapidly, sending up stems and flowering before they have to compete with other vegetation (Manning 2004). Depending on the season's rainfall, seed also germinates in May, with the majority germinating in June and some also into July. Seed is unlikely to be viable in the soil for more than two years (Brown pers comm. 2008).

Plants grow rapidly, reach maturity and flower in two to three years. Individuals can produce up to ten yellow upright flowers, each producing capsules that contain up to 100 seeds (Weeds CRC 2003). This can result in infestations of up to 2,000 plants in a square metre. Yellow soldier has been observed to produce a prolific number of bulbils around the base of stems left on the soil surface this does not appear to be a common method of reproduction or dispersal in Australia (Weeds CRC 2003).

Most *Lachenalia* species are pollinated by different species of solitary bees; some tubular and especially orange-flowering species are pollinated by sunbirds (Manning 2004). The pollinators of yellow soldier in Western Australia is unknown.

The discrete nature of most populations suggests that seed is not naturally spread easily over long distances. Human activity rather is the main cause of medium to long distance seed dispersal. In areas where new plants have established 50 to 100m beyond main infestations, mammals or birds are thought to be dispersers of the seed (Weed CRC 2003).

Yellow soldier appears to tolerate, regenerate and flower well following fire. Being annually renewed, the bulbs are able to survive the heat of the fires whilst underground; fire also clears the soil surface of competing vegetation as well providing fertiliser through an ash-bed (Manning 2004). Fire can cause large production of seed, reduce competition from native species and create bare areas for yellow soldier populations to proliferate (Weeds CRC 2003).

Yellow soldier has the ability to invade both intact and disturbed bushland, causing severe impacts on biodiversity. It is already established in a number of high conservation value bushlands across Perth, and threatens a significant number of other regionally significant conservation areas, such as The Spectacles Wetlands, Thomson's Lake Nature Reserve and Bold Park. Once established in medium to high densities, it displaces native herb and annual plant species, causing loss of plant diversity, destroying habitat and resources for native animals and altering the ecological balance. Severe infestations can also reduce the recreational and aesthetic enjoyment of bushland by people (Weeds CRC 2003).

7. LEGISLATION

There is currently no post-border State legislation to control yellow soldiers but as part of the Alert List for Environmental Weeds, it is marked for eradication (Weeds CRC 2003).

9. CONTROL METHODS

A calendar of yellow soldier growth, flowering, seed production and germination times in south-west Western Australia is presented in Table 3.

Table 3: Calendar of biology and management.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Growth												
Flowering												
Seed production												
Germination												
Physical removal												
Herbicide application												

Preventing new invasions of yellow soldier is more cost effective than having to control established infestations. Early detection and eradication are important to prevent establishment of new populations and expansion of existing populations. Small infestations can be easily eradicated if detected early, however, ongoing commitment is needed to ensure new infestations do not establish (Weeds CRC 2003).

With established infestations of any bulbous species, there are a number of difficulties associated with trying to undertake control in bushland. The choices of herbicides which can be safely used is limited, and manual removal can be time consuming and result in excessive soil disturbance, leading to greater weed re-infestation. Fire is not recommended to use in controlling yellow soldier, because of its tolerance to fire and prolific post-fire seed set. However, unplanned fire events can provide an opportunity to prevent further spread and establishment of new plants. In the post-fire environment, plants are clearly visible and reduced cover of native vegetation makes the flowering bulbs easy targets for herbicide control (Weeds CRC 2003).

A three-year study on control methods carried out by Brown *et al* (2002) produced information on control and management. The study identified two main options for control: herbicides and physical control.

Herbicide control

Herbicide trials have shown some success controlling yellow soldier using 2.5g/ha of metsulfuron methyl (Aim[®], Brushoff[®]) with the penetrant Pulse[®] at 100ml/100L (Brown and Brooks 2002). The timing of application appears to be critical to the herbicides impact. Previously it was suggested spraying at corm exhaustion just on flowering was the optimum treatment time, however, recent results from monitoring and field observations indicate corm exhaustion occurs well before any flowers are visible. Thus, optimum treatment times may be much earlier in mid to late June/early July as opposed to mid-to-late July/early August. Optimum application times are also very seasonal and can vary from year-to-year. There are other herbicides which may be as or more effective and appropriate for use in bushland, however, they are yet to be trialed.

Hand removal

In sandy soils, the bulbs of yellow soldier can be removed by hand cutting the roots with a knife and removing them with the bulb. This can be done from July through to early September. This method is difficult and time consuming and can result in soil disturbance, which can in turn encourage further weed invasion. This may be impractical on a larger scale, particularly given the density at which yellow soldier can occur (Brown *et al* 2002).

8. MANAGEMENT

Vision

The main vision for management is *to contain spread and reduce the distribution of yellow soldier in the Swan NRM Region, with a long term aim to eradicate yellow soldier at key sites, thereby protecting the region's high biodiversity value assets.*

Management objectives

This vision may be achieved with the following strategies:

- contain spread to existing range
- control and eradicate outlying populations
- reduce impacts at selected areas
- control and eradicate populations at high biodiversity value sites
- exclude and prevent yellow soldier from establishing at key high biodiversity value sites. For example Bush Forever sites, Threatened Ecological Communities (TECs), regionally significant remnant vegetation and areas containing significant flora and/or fauna
- increasing awareness of yellow soldiers and responsible gardening
- mapping to reveal extent of remaining populations
- manage upstream and uphill source populations, including drain outlets
- manage human activities, including garden waste dumping, road maintenance and housing development
- foster and continue to develop partnerships between friends groups and land managers such as local government and community groups
- partnership commitment, undertake discussion with partner organisations to develop a framework to monitor in the long term
- maintain a detection and surveillance program.

Targets

To fulfill the aims of the strategy, the following targets should be met in the Swan NRM Region by 2011, unless otherwise stated:

1. *no net increase in the number of populations*
2. *no net increase in range of distribution*
3. *eradication of mature plants at outlying populations and select high biodiversity value sites (Table 1).*

Actions to date

Initiatives have commenced to make land managers aware of the weed, on-ground survey has been undertaken and the control program of populations on the Swan Coastal Plain has been expanded. The intent is to eliminate select populations, ensure new populations are controlled before they establish and significantly reduce the threat of the species becoming a serious environmental weed in south-west WA. The following actions have been or are currently being implemented:

1. Survey to understand the extent and distribution

After gathering all herbarium collection information, field surveys were undertaken in 2006/7 to better understand the distribution and extent of populations. Reports were sought from the community and

land managers on any new or previously unknown populations. Details of each population is listed in Table 3.

2. Raised industry and community awareness

Images, descriptions and general information on the species have been disseminated in a number of forms, including electronic media, public forums and print media.

3. Liaison with land managers

Liaison has commenced with the majority of land managers where yellow soldier occurs.

4. Mapping of populations at key sites

Mapping of yellow soldier has been undertaken by at least two LGAs. Detailed mapping using differential Global Positioning System (GPS) was undertaken at other key sites.

5. Assessment of biodiversity values of sites containing each population and identification of high conservation value sites in close proximity, which could be at risk from invasion.

Locations were plotted in Geographic Information System (GIS) with various data layers added, including biodiversity assets such as Bush Forever sites and TEC's. Maps of these layers for sub-sections of the region are in Figures 8 to 10. Bush Forever Volumes 1 and 2 (Government of Western Australia 2000) were used to assess the conservation values of each site listed. Sites were also inspected and assessed in the field. These give a visual representation of spread and allow assessment of which sites are most at risk.

Each population was then assessed and rated by several criteria (described in Table 4):

- conservation value of site
- feasibility of control
- whether it is an outlying population
- threat posed to nearby biodiversity assets.

Values and ratings are listed in Table 1. Eighteen populations occur in high biodiversity conservation areas and were rated very high or high priority for management. These areas include Bush Forever sites, are in or adjacent to TEC's, and/or contain significant flora or fauna. A number of other priority populations occur in or near areas of significant conservation value such as national parks, regional parks, TEC's and/or significant areas of remnant vegetation. Outlying populations were given special consideration for management in addition to the site's conservation value.

6. Development of an implementation plan, aimed at first eradicating small to medium-sized populations within or in close proximity to high conservation value sites, and outlying populations.

Specific short-term (2007-2008) and long term management recommendations have been developed for sites rated very high (VH), high (H) and moderate (M), as well as lower management priority sites (Table 1). Most of these actions involve herbicide spraying, monitoring and surveillance.

Recommended actions

The following actions are recommended:

1. Continue and expand control program to all known sites, based on priorities outlined in Table 1.
2. Continue liaising with land managers including DEC and LGA's, as well as other NRM groups, the community, Main Roads WA and the Water Corporation.
3. Conduct further surveys for unknown populations outside the Swan NRM Region, including identification of priority areas (eg, Yellagonga Regional Park, Beeliar Regional Park).

4. Monitor known population sites annually and continue mapping program.
5. Establish a process of detecting, reporting and eradicating new infestations. Early detection and eradication of small populations are important to prevent spread and escalation of threat to biodiversity.
6. Prevent further invasion and new populations appearing in bushland - remove other sources within areas such as gardens/parks before they invade natural ecosystems.
7. Obtain further biological and ecological information, particularly on general biology and impacts on native plant communities. Improved knowledge will provide a scientific basis for management.
8. Maintain quarantine, prevent from spreading - prohibit propagation, cultivation and sale in Western Australia, no importation of *Lachenaia* species.
9. Continue to increase understanding and awareness in the community and amongst land managers through an information brochure, liaison and other means.
11. Trial use of alternate herbicide/s for use on yellow soldier in bushland – testing other herbicides including Dalapon, which may be more effective, less residual and present less risk to native vegetation.
11. Keep fire and other disturbance factors out of high biodiversity value sites.

Resources

This strategy will help determine funding priorities for the SCC's investment planning process. Funds have been available for control of some infestations in 2006 and 2007 as part of DEC's Saving Our Species Biodiversity Conservation Initiative (BCI). Thirty thousand dollars a year over two years has enabled mapping, survey and herbicide spraying at key infestations to be undertaken, however, it is yet to be confirmed whether this funding will be continued beyond 2008. To continue the program of yellow soldier control and eradication, this funding commitment would be required for a period of five to 10 years. As one of the leading conservation agencies with the relevant expertise, DEC should provide resources in the form of a coordinating project officer and funds to continue implementing recommendations. As yet, other funding sources or contributions potentially available from LGA's are unknown.

Stakeholders

The populations currently known occur on public lands vested in a range of agencies. Developing partnerships with these organisations is integral to achieving the desired outcomes of the strategy. The key agencies include:

- Swan Catchment Council
- Department of Environment and Conservation
- Local Governments – City of Cockburn, City of Melville, City of Fremantle, City of Joondalup, City of Nedlands
- Department of Agriculture and Food Western Australia
- Water Corporation
- The nursery industry
- Community members
- Friends groups.

9. MONITORING AND EVALUATION

Monitoring and evaluation are key parts of measuring successful implementation of this strategy. New information can also provide the basis to adapt the management program. At the completion of three years (July 2011), the strategy should be reviewed and evaluated against the management targets. With baseline information already gathered, data needs to be re-collected in 2011 to assess the spread/decline of yellow soldier and evaluate the success or progress toward management targets. Indicators to show this include:

1. surveying for expansions in existing and new populations
2. mapping; spatial data can identify changes in distribution and numbers of plants
3. record number/density of plants for populations and quadrat-based monitoring (recording numbers of individuals and percent cover).

As further information is gathered, the strategy and management approaches may be adapted. Because of the long-lived bulbs, monitoring and management actions will need to be carried out for up to ten years.

10. CONTACTS

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Swan Catchment Council. Phone (08) 9374 3333.

11. ACKNOWLEDGMENTS

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12. REFERENCES

Australia's Virtual Herbarium, via Centre for Plant Biodiversity Research, Council of Heads of Australian Herbaria <http://www.anbg.gov.au/avh/> (accessed 5 May 2007).

Brown, K. and Brooks, K (2002) *Bushland Weeds: A practical guide to their management*, Environmental Weeds Action Network, Greenwood.

Brown, K., Brooks, K., Madden, S. and Marshall, J. (2002) Control of the exotic bulb, Yellow Soldier (*Lachenalia reflexa*) invading a Banksia woodland, Perth, Western Australia. *Ecological Management and Restoration*, **3** (1): 26-34.

Brown, K. (2008) Personal communication.

CRC for Australian Weed Management (2003) *Weed Management Guide: Yellow Soldier – Lachenalia reflexa*, Commonwealth Department of the Environment and Heritage, Canberra.

Duncan, G. (2003) *Lachenalia salteri*, Royal Botanic Gardens, Kew, Blackwell Publishing Ltd, Oxford, UK.

Duncan, G.D. and Linder Smith, C. (1999) *Liliaceae*, Flowering Plants of Africa, National Botanical Institute, 56: 14-17.

Government of Western Australia (2000) *Bush Forever Final Report, Volumes 1 and 2*, Western Australian Planning Commission, Perth, Western Australia.

Hussey, B.M.J, Keighery, G.J., Dodd, J., Lloyd, S.G. and Cousens, R.D. (2007) *Western Weeds – A Guide to the Weeds of Western Australia*, Second edition, Weeds Society of WA (Inc), Victoria Park.

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Macfarlane, T.D, Watson, L. and Marchant, N.G. (Editors) (2000 onwards) Western Australian Genera and families of Flowering Plants, Western Australian Herbarium, <http://florabase.calm.wa.gov.au/browse/flora/f=054h&level=g&id=389> Accessed November 2007.

Manning, J. (2004) Family: Hyacinthaceae, Compton Herbarium, South Africa National Biodiversity Institute, <http://www.plantzafrica.com/planthij/hyacinth.htm> Accessed 2 January 2008.

Pacific Bulb Society (2007) *Lachenalia Species Four*, <http://www.pacificbulbsociety.org/>, Accessed 3 December 2007.

Scott, J.K., Yeoh, P., Batchelor, K. and Ota, N. (2008) *Modelling climatic change impacts on sleeper and alert weeds*, unpublished, CSIRO, Floreat, Western Australia.

Western Australian Herbarium (2007) Hyacinthaceae: *Lachenalia reflexa* Thunb. <http://florabase.calm.wa.gov.au>, Accessed 5 November 2007.

United States Department of Agriculture (USDA) (2000) *Lachenalia reflexa* Thunb., Germplasm Resources Information Network (GRIN), <http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?21311> Accessed 3 December 2007.

13. FIGURES AND TABLES



Figure 1: Major management boundaries of the Swan NRM Region, showing NRM sub-regions, DEC regions, districts and Local Government Authority boundaries.



Figure 3: Other *Lachenalia* species found in south-west Western Australia, from left to right; red soldier (*L. bulbifera*) (photo by K. Bettink), spotted soldier (*L. mutabilis*) (photo by K. Bettink) and *L. aloides* (photo by K. Brown).

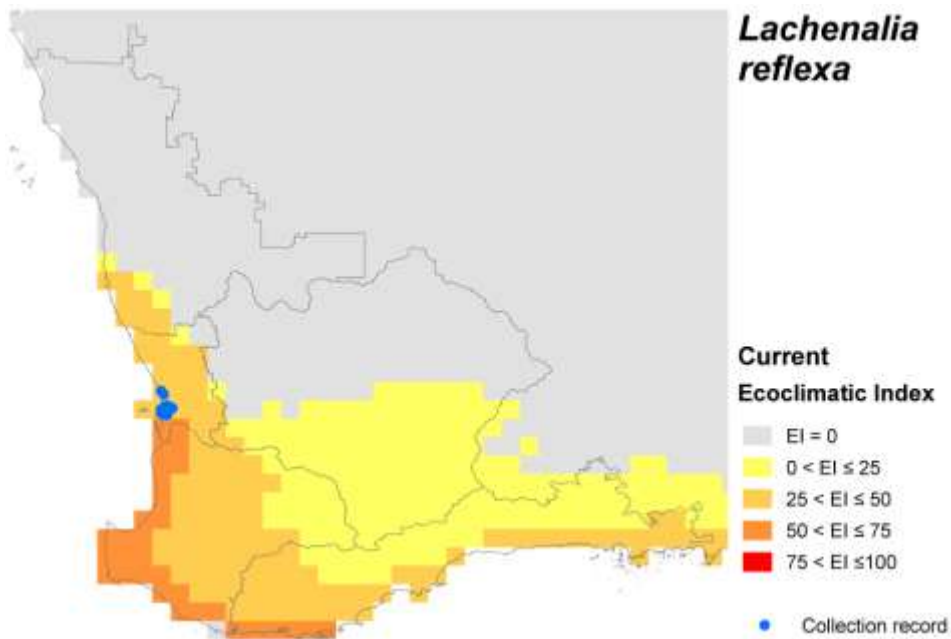


Figure 4: Climex[®] modeling of the potential distribution of yellow soldier in south west Western Australia, undertaken by CSIRO (Scott *et al* 2008).



Figure 6 (left): Banksia woodland with mixed herbaceous understorey in early stages of invasion by yellow soldier; (middle) example of density of plants in understorey (right): prolific numbers of yellow soldier on white, calcareous sands (photos: K.Bettink).

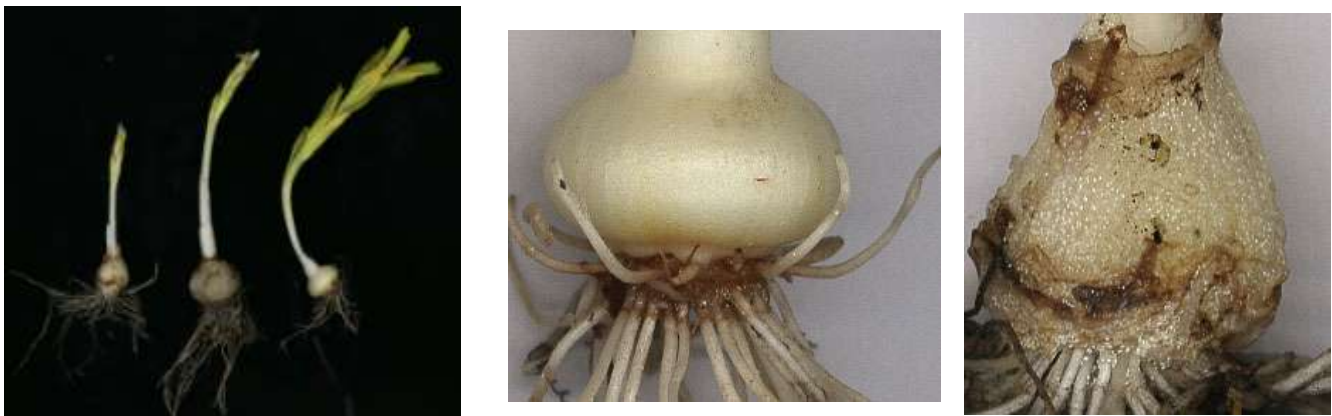


Figure 7: (left to right) three growth stages of yellow soldier showing changes in the bulb from development of flower buds, just before flowering and bulb exhaustion to full flowering and development of the new bulb; detail of exhausted bulb which occurs just prior to flowering; detail of newly formed bulb (photos: K. Bettink).

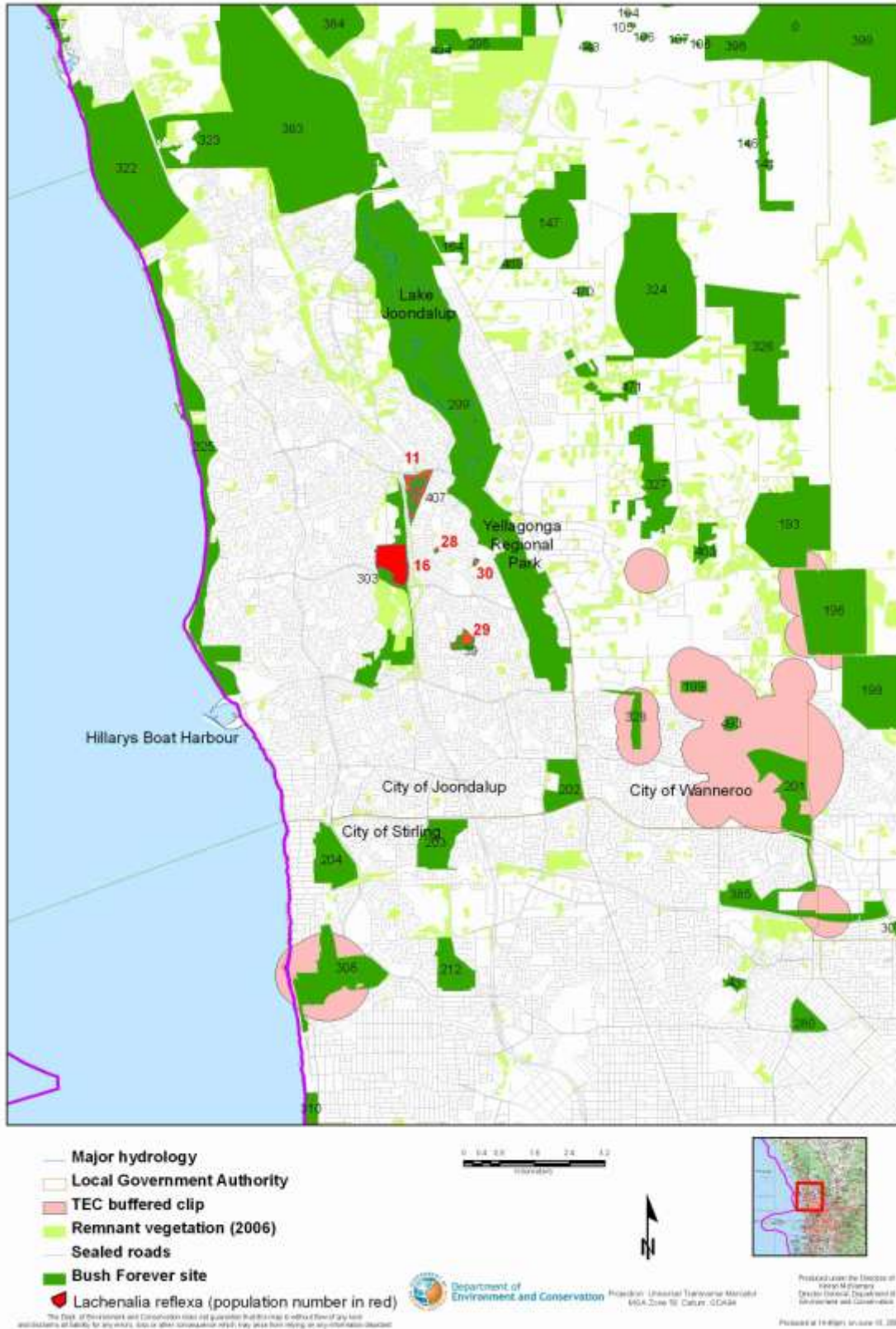


Figure 8: Distribution of yellow soldier populations against biodiversity assets in the north of the region.

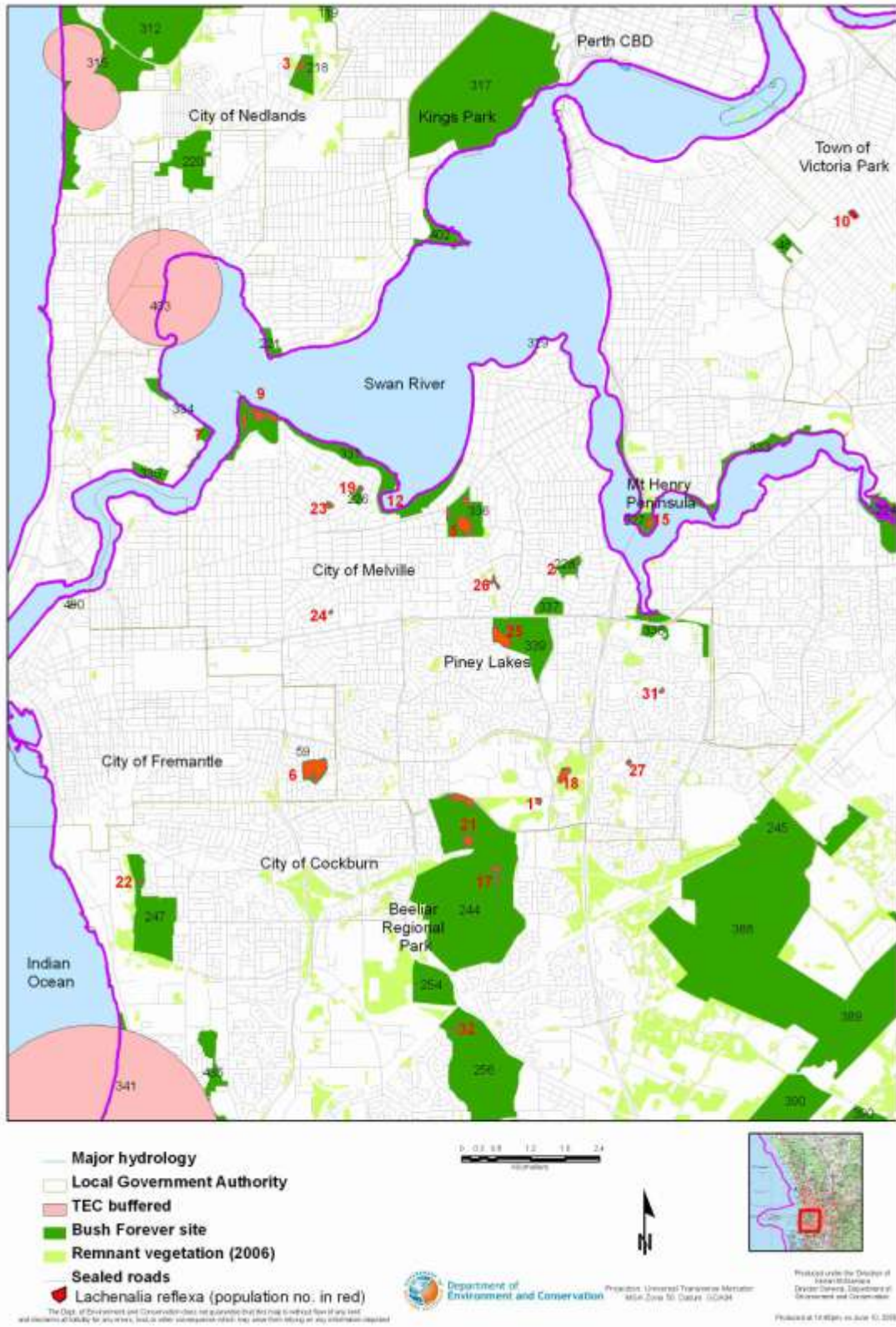


Figure 9: Distribution of yellow soldiers against high biodiversity value assets across the central populations in the Swan NRM Region.



Figure 10: Distribution of yellow soldiers against high biodiversity value assets across the southern populations in the Swan NRM Region.

Table 4: Criteria for assessing sites.

Table below: Criteria for ranking threat to biodiversity values of site (from highest to lowest).

Ranking	Criteria (serves as a guide only)
1	TEC and/or Declared Rare Flora (DRF) present Priority/significant flora species present Regionally significant. Bush Forever site Vegetation in good, very good to excellent condition in majority of site International/nationally significant Contains other special attributes (eg, scientific importance)
2	No TEC or DRF present Priority/significant flora species may be present May be regionally significant May contain other special attributes Vegetation in good to degraded condition Occurs on road verge/buffer adjoining and threatening sites ranked 1 Is outlier population at known extent of range
3	No TEC, DRF or priority/significant flora species present Not recognised as regionally significant No other special attributes Vegetation degraded to poor, completely disturbed or very poor condition (vegetation structure disappeared, few, if any, native species, high percentage cover and abundance of weeds) Does not threaten high biodiversity value sites

Table below: Criteria for ranking feasibility of control of weed species (from high to low feasibility).

Ranking	Criteria (serves as a guide only)
1	Weed in low numbers and/or low density Occasional and localized/confined to a specific area of site and in low density Possibility population/s eradicated in two to three years Site easily accessible
2	Weed in low numbers and/or low density Occasional and widespread-present in most or all of site Weed in medium densities Common and localised-confined to specific areas of site Possibility population/s severely reduced or eradicated within 2 to 3 years Site accessible/moderately accessible
3	Weed in high density Widespread or localised and abundant Infestation difficult to control, eradication unlikely Likelihood infestation would require intensive treatment for over three years Site may be difficult to access Site has complication for management – e.g, sensitive site, permanent water