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Monitoring Protocol

Weed control within Brixton Street Wetlands Herb Rich Shrublands in Clay Pans (FCT 8) Threatened Ecological Community

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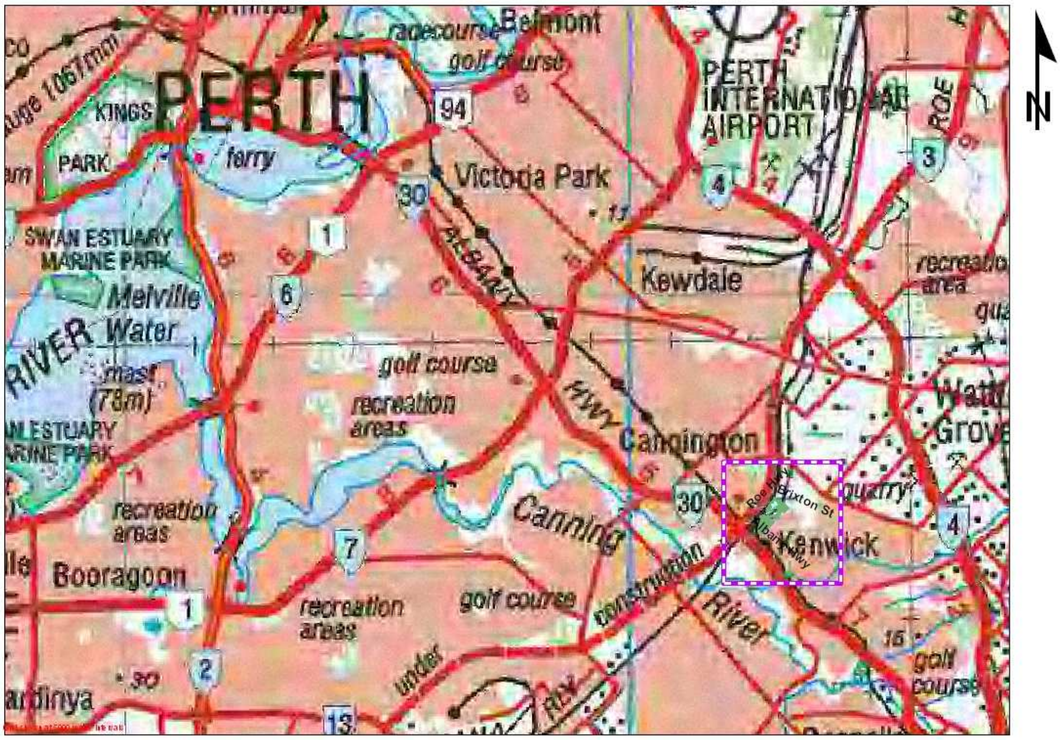
1 Introduction

This protocol provides information and procedures for monitoring the effectiveness of weed control efforts over time within the “herb rich shrublands in clay pans” (floristic community type 8 as described in Gibson *et al*. (1994)) threatened ecological community in Brixton Street Wetlands, Western Australia (**Figure 1**). Part of the information used to develop this protocol comes from Brown and Brooks (2003) “*Sparaxis bulbifera (Iridaceae) invading a clay based wetland on the Swan Coastal Plain – control methods and observation on the reproductive biology*.”



2 Protocol Constituents

This protocol consists of this Protocol Narrative and the following Standard Operating Procedures (SOPs):

SOP 6.2 Establishing vegetation transects

3 Background and Objectives

3.1 Background and history

The Brixton Street Wetlands lie 20 km south east of Perth at the foot of the Darling Scarp. A small 19 ha remnant on the winter wet flats of Guildford formation clays, the wetlands have an exceedingly diverse flora of 307 native taxa (Keighery and Keighery 1991). Species rich herblands cover the winter-wet claypans, herb rich shrublands the clay flats and *Corymbia calophylla* woodland occur on the higher ground where the soil is well drained (Keighery and Keighery 1991). With this kind of habitat almost entirely cleared on the Swan Coastal Plain the area is of outstanding conservation value (Keighery and Keighery 1991, Gibson *et al*. 1994). One of the major threats to the native flora and to the plant communities of the wetlands is invasion and competition from weeds such as *Sparaxis bulbifera*. This South African cormous species is a serious invader of clay based wetlands on the Swan Coastal Plain (Hussey *et al*. 1997). Once established it forms dense monocultures displacing herbaceous flora in particular. Given that around 50% of the native flora at Brixton Street comprises annuals or perennial herbs, many of them rare or restricted taxa, *S. bulbifera* poses a significant threat to conservation values of the wetland.

The floristic community types (FCTs) in the Brixton Street Wetlands include 3a (*Corymbia calophylla – Kingia australis* woodlands on heavy soils - ranked critically endangered) and 8 (herb rich shrublands in clay pans - ranked as Vulnerable) (Gibson *et al*. 1994). A third proposed TEC that is a sub-group of the clay pan type (Gibson *et al*. 2005) is awaiting endorsement through State processes.

Options for control of a weed growing closely among native plants in this these plant communities are limited, particularly at this site where work must be undertaken as the wetlands starts to dry out after winter inundation and prior to *S. bulbifera* coming into full flower. Hand removal is one option in such situations but due to the labour intensive nature and the degree of infestation, an integrated approach which also utilises carefully targeted chemical control is usually more effective. Herbicide trials on *S. bulbifera* in the Brixton wetlands indicated that the herbicide metsulfuron methyl (BrushOff) applied at 2.5g/hectare with the penentrant Pulse, was effective against *S. bulbifera* and had little impact on co-occurring native species (Brown & Brooks 2003, see Appendix A).

3.2 Rationale for selecting this resource to monitor

This protocol was selected to be included with a suite of TEC monitoring protocols because it illustrates the benefits of pre and post-weed control monitoring across a TEC. The monitoring was established 10 years prior to the commencement of the Resource Condition Monitoring (RCM) project.

It is hoped that this protocol will be able to be reviewed and adapted by nature conservation staff for their own weed control monitoring in similar plant communities.

3.3 Measurable objectives

The objective of this protocol is to monitor the effectiveness of weed management across the TEC over time. This includes detecting change in the populations of the invasive plant as well as changes in the occurrence and cover of all native species.

4 Sampling Design

4.1 Rationale for selecting this sampling design over others

The use of 1m x 1m quadrats was selected to allow accurate counts of *S. bulbifera* (up to 1000 individuals in a 1m x 1m plot) and accurate cover estimates of natives and weeds to be undertaken. Additionally consideration was given to the sensitive nature of the clay-based plant community and its susceptibility to damage through access and trampling.

To monitor the effectiveness of weed management and changes in the impacted plant community over time, three 30m transects were run from the disturbed edges of the bushland into intact areas. Six 1m x 1m quadrats were placed at 5m intervals along each transect. Transects were selected so changes in the spread of *S. bulbifera* away from the disturbed edge could be detected.

4.2 Site Selection

4.2.1 Criteria for selection

The Brixton Street wetlands contain one of the most intact and largest occurrences of FCT 8. Given that weed control work had already been undertaken at this site, it was prioritised for protocol development.

4.2.2 Procedures for selecting sampling locations

Sampling locations were situated wholly within the mapped boundary of FTC 8 in areas that had some degree of Sparaxis infestation.

4.3 Sampling recommendations: frequency and replication; number and location of sampling sites; frequency and timing of sampling

Three 30m monitoring transects were placed 10m apart within the TEC in the area most affected by the *S. bulbifera* invasion (Figure 2). The first monitoring was undertaken in September 1998 before any control work on *S. bulbifera* had taken place. The transects were rescored in September 1999. The results indicated a significant increase in the *S. bulbifera* population and a hand weeding program was instigated that year. When hand weeding across the entire site was found to be impractical the decision was made to investigate herbicide options. In August 2000, herbicide trials were developed and established in another area of the Brixton Street Wetlands, the results of which were published (Appendix A). The herbicide techniques developed as a result of those trials were used, in conjunction with targeted hand removal across the TEC in 2002. The transects are now rescored every 3 years to monitor effectiveness of the control program and recovery of the native plant community over time (last scored in 2008).

Figure 2 **Location of monitoring plots within FCT08 TEC in the Brixton Street Wetlands**

4.4 Amount/type of sampling that is required to detect a pre-specified change

In order to detect a 10% decrease in *S. bulbifera* numbers it was estimated 3 x 30m transects were required within the TEC. The sampling was also designed to detect significant changes in native plant cover or any change in cover of weeds apart from *S. bulbifera* at the site.

5 Field Methods

5.1 Field season preparations and equipment setup

Monitoring transects were established to record change in the *S. bulbifera* population and native plant cover over time in 1998. Research was undertaken to investigate suitable methods of control for the target weed species *Sparaxis bulbifera* in 2000. A suitable area of infestation was selected to establish monitoring transects and the necessary equipment was ordered and prepared.

5.2 Sequence of events during field season

During the field season the following steps were undertaken:

- Establishment and scoring of monitoring transects in early September 1998 (Figure 2a).
- Rescoring in early September 1999 before work on *S. bulbifera* for that season commenced. (the results of the monitoring work reflects the effectiveness of the previous seasons work).

5.3 Details of taking measurements, with example field forms

For each plot along the transects, the number of *S. bulbifera* adults (flowering plants) and juveniles (non-flowering plants) in each plot were counted and a cover estimate (Braun-Blanquet) scored for each species (native and introduced) in each plot. Information was recorded in a specifically designed field form (Appendix B).

A Threatened Ecological Community Occurrence Report Form may also be filled out (contact Department of Environment and Conservation, Species and Communities Branch, TEC specialist group).

5.4 Post-collection processing of samples

All plant species that were not able to be easily identified in the field were collected for identification at the WA Herbarium. Collections were correctly labelled, put in newspaper within a plant press and placed in herbarium driers prior to identification.

5.5 End-of-season procedures

The following tasks are to be undertaken at the end of the field season:

- plant specimens processed, identified, mounted, boxed and sent to the WA Herbarium for incorporation;
- equipment has been cleaned, stored and is ready for the next season;
- data sheets updated to incorporate correct plant identifications;
- data entered into an Access database using ‘Max’, a data entry tool that allows keeping taxonomic nomenclature up to date via the census of Western Australian plants;
- data analysis; and
- report preparation.

6 Data Handling, Analysis and Reporting

- The collected data is stored in an Access database linked to the census of Western Australian Plants.
- Multivariate analyses are used to detect change in cover and diversity of native and introduced flora over time (Primer 6, Clarke and Warick 2001).

- The results are used to review the effectiveness of management actions on *S. bulbifera* and to then guide future works in the Brixton Street Wetlands.
- Reporting has been through presentations, and newsletter articles. The results will be written up as a scientific publication.

6.1 Metadata procedures

Metadata is “data about data”. That is, a statement about a dataset which describes the content, quality, currency and location and custodianship of the data. The Australia New Zealand Land Information Council has developed guidelines for the collection of metadata (ANZLIC 2001). Metadata collection under this protocol will be compliant with these guidelines.

Metadata statements that may be created for data collected during this project (for example spatial data or transect data) can be created in a Word document or text file and should be saved in the same directory as the dataset.

6.2 Overview of database design

DeBacker *et al*. (2004) note that foresight in database design is integral to ensuring data quality. An Access database is considered to be the most appropriate database for storage of data from this project. An Access database allows the data entered to be used to create tables, queries, forms and reports.

6.3 Data entry, verification and editing

Data was entered into an Access database using the ‘Max’ data entry program developed by the Western Australian Herbarium. This ensures up to date taxonomy is maintained within the database.

As noted in DeBacker *et al*. (2004), data verification should immediately follow data entry and involve checking the accuracy of electronic records against the original source (eg. paper field records). Once the electronic data have been verified as accurately reflecting the original field data, the paper forms can be archived) and the electronic version used for all subsequent data activities.

7 Personnel Requirements and Training

7.1 Roles and responsibilities

The following is an example of staffing requirements for a similar style monitoring program:
Project team leader:

- devises management action to be monitored;
- co-ordinate field visits;
- team logistics (delegation); and
- finalise protocols.

Botanist/Ecologist:

- Assist with identification of plant specimens;

Biometrician

- assist in statistical design;
- run analyses; and
- assist in interpretation of findings.

Project/Field officer:

- apply GIS applications such as ArcMap 9;
- enter data into the relevant database applications;
- organise field visits (equipment etc);
- assist with or undertake field work; and
- write up reports in liaison with Botanist/Ecologist and Statistician.

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Technical advice for this monitoring project was sought from experienced staff (Bob Dixon Botanical Gardens and Parks Authority and John Moore (Department of Food and Agriculture WA) on herbicide treatments.

A spray contractor with knowledge of the Brixton Street flora and with a background in bushland work carried out herbicide applications in more heavily infested areas of Brixton Street during the establishment of this project.

7.2 Qualifications

Although monitoring is not technically a flora and vegetation survey, it does contain an inventory of the flora that requires a certain level of skill and awareness. For that reason the following EPA recommendation is included from "Guidance for the Assessment of Environmental Factors Western Australia (in accordance with the Environmental Protection Act 1986) No. 51 (June 2004)":

"Flora and vegetation surveys should be coordinated and led by botanists who have had training, mentoring and experience in flora and vegetation survey. It is expected that they will have specific training and/or experience in ecology and taxonomy of the Australian flora and would normally have had a wide exposure to WA's flora and vegetation, preferably with knowledge and experience in the region being surveyed.

It is recognised that some surveys may be done by survey teams that include members with less experience. These members should be supervised and mentored by the specialists mentioned above. This is seen as useful in training new practitioners."

7.3 Training procedures

Training is essential for developing competent observers. A refresher on species identification, GPS navigation, compass use, and foliar cover estimation may be necessary for observers. Observers should be trained to undertake all SOPs relevant to this protocol.

8 Operational Requirements

8.1 Annual workload and field schedule

Monitoring takes place every three years, and takes two people, two days field work and a further 10 days to identify and process specimens and enter and check data. This does not include the actual time taken to manage *S. bulbifera* at the site, only the time to monitor the outcomes of that work.

8.2 Facility and equipment needs

Aside from general office facilities and equipment requirements, a range of computer hardware and software for data entry, storage and analyses are required. A GPS, or differential GPS may be used to record the transect start and end points.

8.3 Startup costs and budget considerations

The work at Brixton Street Wetlands is part of a project initiated by the Environmental Weeds Action Network and funded through the Natural Heritage Trust Bushcare Program and the Lotteries Commission. The project has been managed by the Department of Environment and Conservation's Urban Nature Program and Swan Coastal District for the last 5 years.

9 References

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10 Appendix

Appendix A: *Sparaxis bulbifera* (Iridaceae) invading a clay based wetland on the Swan Coastal Plain – control methods and observations on the reproductive biology (Brown and Brooks, 2003)

Sparaxis bulbifera (Iridaceae) invading a clay based wetland on the Swan Coastal Plain – control methods and observations on the reproductive biology

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Summary

***Sparaxis bulbifera*, a cormous geophyte from the Cape Region of South Africa, is a serious invasive weed of clay based wetlands on the Swan Coastal Plain. Where it invades these wetlands it forms dense monocultures, displacing much of the rich native herbaceous flora. Herbicide trials were conducted in the Brixton Street Wetlands south east of Perth, where it is invading shrublands and herblands, and impacts of treatments on co-occurring native species recorded. Metsulfuron methyl was trialed at 1.0 g ha^{-1} and at 2.5 g ha^{-1} and chlorsulfuron at 2.5 g ha^{-1}. All treatments significantly reduced the number of juvenile and adult plants of *S. bulbifera*. Metsulfuron methyl at 2.5 g ha^{-1} was the most effective reducing the number of adult plants per plot from a mean of 25.4 to 0.4 and the number of juvenile plants from a mean of 373.2 to 28.8.**

There were 27 species of native taxa scattered across the trial plots and only two taxa, *Sowerbaea laxiflora* and *Philydrella drummondii* appeared to have been adversely affected by the herbicide treatments. The results however were compounded by the spatial distribution and the seasonal nature of the native flora. Additional information on the reproductive biology and spread of the weed was also recorded.

Introduction

The Brixton Street Wetlands lie 20 km south east of Perth at the foot of the Darling Scarp. A small 19 ha remnant on the winter wet flats of Guilford formation clays, the wetlands have an exceedingly diverse flora of 307 native taxa (Keighery and Keighery 1995). Species rich herblands cover the winter-wet claypans, herb rich shrublands the clay flats and *Eucalyptus calophylla* woodland the higher ground where the soil is well drained (Keighery and Keighery 1991). With this kind of habitat almost entirely cleared on the Swan Coastal Plain the area is of outstanding conservation value (Keighery and Keighery 1991, Gibson *et al.* 1994). One of the major threats to the native flora and to the plant communities of the wetlands is invasion and competition from weeds such as *Sparaxis bulbifera*. This South African cormous species is a serious invader of clay based wetlands on the Swan Coastal Plain (Hussey *et al.* 1997). Once established it forms dense monocultures displacing herbaceous flora in particular. Given that around 50% of the native flora at Brixton Street comprises annual or perennial herbs, many of them rare or restricted taxa (Keighery and Keighery 1995), *S. bulbifera* poses a significant threat to conservation values of the wetland.

Options for control of a weed growing closely among native plants in a wetland situation are limited. At Brixton Street any control program needs to take place over a short time at the beginning of October as the wetland begins to dry out and before *S. bulbifera* comes into full flower. Hand removal at this time is one option and is a particularly useful tool for removing small isolated populations growing in relatively undisturbed bushland. However hand removal is labour intensive and consequently needs to be integrated with a carefully targeted chemical control program. Trials in recent years have indicated that the sulfonylurea group of herbicides can be quite effective against a number of introduced bulbous and cormous species (Pritchard 1991, Dixon 1996, Pritchard 1996, Peirce 1998, Meney 1999, Brown *et al.* 2002). Observations and data indicate that some introduced bulbous or cormous species invading bushland can be controlled with sulfonylurea herbicides with minimal impact on the native flora (Dixon 1996, Meney 1999, Moore 1999). Brown *et al.* (2002) in detailed studies on the control of *Lachenalia reflexa* with metsulfuron methyl at 5 g ha^{-1} in a *Banksia* woodland found indications of minimum impact on co-occurring native species.

With little published information on herbicide control of *S. bulbifera* this study aimed to trial the effectiveness of two herbicides, metsulfuron methyl and chlorsulfuron on *S. bulbifera* and to investigate the impacts of these herbicides on co-occurring native species in the Brixton Street Wetlands.

Methods

Trial plots (1 m × 1 m) were laid out in a randomized block design (control and three treatments) with five replicates of each treatment. In August 2000, before treatment, the number of *S. bulbifera* adults (flowering plants) and juveniles (non flowering plants) in each plot was counted and a cover estimate (Braun-Blanquet) scored for each species (native and introduced) in each plot. In early October 2000 the herbicide was carefully spot sprayed in each treatment. As this weed grows very closely amongst the native herbs and shrubs these were also subject to herbicide application. Metsulfuron methyl (Brushoff®, 600 g kg^{-1} metsulfuron methyl) was applied from a 15 litre backpack sprayer at 2.5 g ha^{-1} and at 1.0 g ha^{-1} and chlorsulfuron (Glean®, 750 g kg^{-1} chlorsulfuron) was applied at 2.5 g ha^{-1}. All were applied with the penetrant Pulse® (1000 g L^{-1} polydimethylsiloxane) at 2 mL L^{-1}. The plots were rescored in September 2001. Differences in counts between treatments and years were analysed using Kruskal Wallace ANOVA with post hoc Mann-Whitney U-tests used to determine significance between individual treatments. Plant nomenclature generally follows Paczkowska and Chapman (2000).

Plants of *S. bulbifera* were also monitored over time to determine bulbil and seed production and methods of spread.

Results

Sparaxis bulbifera control

All herbicide treatments significantly reduced the number of both adult and juvenile *S. bulbifera* plants in the trial plots. Metsulfuron methyl at 2.5 g ha^{-1} was the most effective followed by chlorsulfuron at 2.5 g ha^{-1} then metsulfuron methyl at 1.0 g ha^{-1}. Metsulfuron methyl at 2.5 g ha^{-1} was significantly more effective than metsulfuron methyl at 1.0 g ha^{-1} in controlling adult plants (Figure 1). Apart from this there were no significant differences between treatments. Although all treatments significantly reduced the number of juvenile plants, a mean of 28.8 (±15.08) individuals per plot still remained following the most effective treatment (Figure 2).

Herbicide impacts on native plants

There were 27 species of native plants recorded from across the trial site; five shrubs, 14 perennial herbs (seven of those geophytes) and eight annual herbs. Not all species occurred in all plots. Of the five shrubs, three species remained unchanged or increased in cover across all the herbicide treatment plots they were present in. Seedling recruits of *Viminaria juncea* and *Pimelia imbricata* var. *major* were observed in some treatment plots. Of the remaining two taxa, *Verticordia densiflora* fluctuated in cover across the chlorsulfuron plots while *Kunzea micrantha* subsp. *micrantha* decreased in cover, across both metsulfuron treatments and fluctuated across the controls.

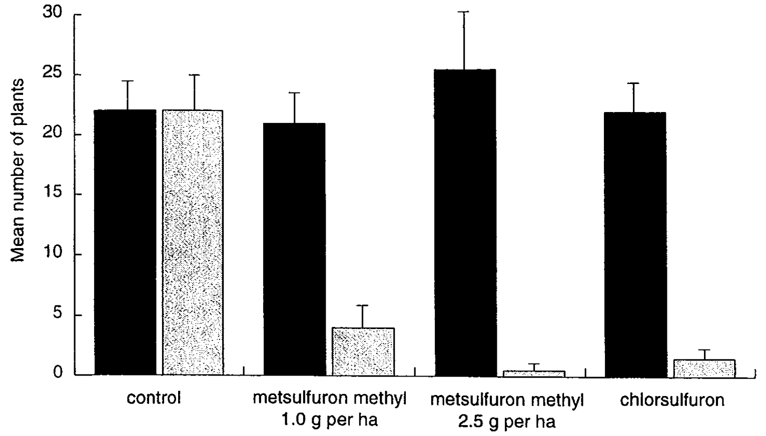

Figure 1. Mean number (with standard error bars) of mature *Sparaxis bulbifera* plants in treatment plots (1 x 1 m) before (dark) and after (pale) herbicide treatments.

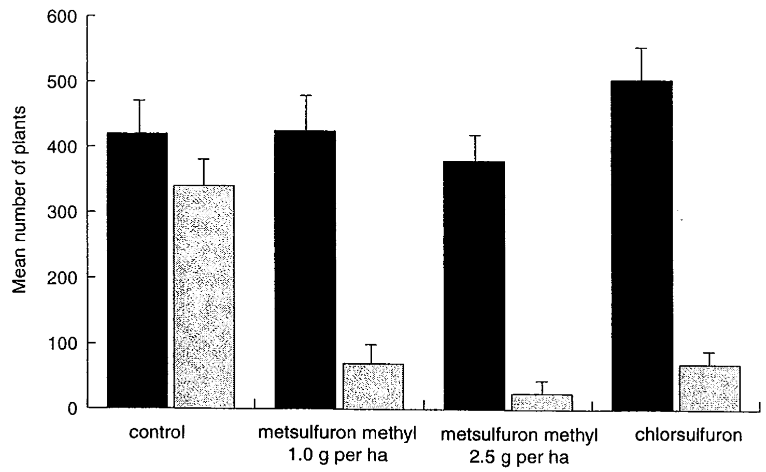

Figure 2. Mean number (with standard error bars) of juvenile *Sparaxis bulbifera* plants in treatment plots (1 x 1 m) before (dark) and after (pale) herbicide treatments.

Of the 14 perennial herbs present, eight taxa retained or increased cover within all treatment plots in which they occurred (Table 1). Cover fluctuated across one or more herbicide treatment plots for two taxa, *Borya scirpoidea* and *Drosera menziesii* subsp. *menziesii*. *Sowerbaea laxiflora* decreased in the control plots it occurred in and cover class fluctuated under both metsulfuron methyl at 2.5 g ha^{-1} and chlorsulfuron at 2.5 g ha^{-1}. In one of the chlorsulfuron treatment plots cover of *Sowerbaea laxiflora* decreased from 25–50% cover to zero. For one taxon, *Cyathochaeta avenacea*, cover fluctuated across control plots only. Of the remaining two perennial herbs, *Utricularia menziesii* decreased in cover across all plots it occurred in including controls. *Philydrella drummondii* decreased in all the metsulfuron methyl (2.5 g ha^{-1}) and chlorsulfuron (2.5 g ha^{-1}) treatment plots in which it occurred (Table 1).

There was a high level of recruitment into both control and herbicide treatment plots of annual herbs with four taxa retaining cover or recruiting into the treatment and control plots over 2000/2001 (Table 1). One taxon, *Hydrocotyle alata*, recruited into control and metsulfuron (1.0 g ha^{-1}) treatments with cover fluctuating under the other two treatments. Of the remaining three taxa, two retained cover in all treatment plots they occurred in and one, *Drosera glanduligera*, decreased in cover in the only treatment plots in which it occurred, metsulfuron methyl (1.0 g ha^{-1}) (Table 1).

Observations on reproductive biology and spread

Observations over the period of our study have provided insights into some aspects of the reproductive biology of *S. bulbifera* including seed biology, mechanisms of dispersal and patterns of invasion within the wetland. Although plants produce small bulbils up the stems as they die down at the end of each season, populations appear to spread mainly by seed. Each plant produces around 75 soft thin papery coated seeds in late spring and within the wetlands at least, water appears to be a major dispersal agent. The seed has been observed floating in standing and flowing water and maps reveal populations moving mainly through low lying wet areas including creeks and drains. Sheet water flow occurring across the wetland in winter may well explain small populations of *S. bulbifera* appearing in undisturbed bushland. There is also evidence that human activities are playing a role in the spread of the population with dense infestations occurring along walking tracks.

Interestingly the seed appears to be relatively short lived in the soil, generally germinating the first season following ripening. Prolific seedling recruitment was observed throughout populations of *S. bulbifera* before the management program began. One year following removal of all flowering plants from isolated populations little or no seedling recruitment was observed in those populations.

Discussion

Effectiveness of treatments and impacts on native taxa

It is clear that the herbicides tested all effectively controlled *S. bulbifera* at the trial sites, with metsulfuron methyl at 2.5 g ha^{-1} the most effective. The high number of juvenile plants remaining in the treatment plots indicates that there will need to be follow up control and any successful management strategy will require a commitment of on-ground resources over a number of years.

As not all native taxa occurred in all treatment or control plots, impacts of the three herbicide treatments on the native flora at Brixton Street is unclear. This is compounded by the highly seasonal nature of the wetland flora. Nevertheless the results do indicate that effective control of *S. bulbifera* is possible with minimum impacts on a range of native taxa. The only shrub at the site that gave an indication of being affected by metsulfuron treatments, *Kunzea micrantha* subsp *micrantha*, also showed a fluctuation in cover across the control plots, increasing in some and

Table 1. Changes in cover class among co-occurring native taxa following the three herbicide treatments to *Sparaxis bulbifera*.

Taxa	Life form	Control	Metsulfuron methyl 1.0 g ha^{-1}	Metsulfuron methyl 2.5 g ha^{-1}	Chlorsulfuron 2.5 g ha^{-1}
Acacia lasiocarpa var. *bracteolata*	shrub	≥	–	≥	≥
Aphelia cyperoides	annual herb	–	–	≥	≥
Borya scirpoidea	perennial herb	≥	±	≥	–
Burchardia congesta	perennial herb-geophyte	≥	–	–	–
Burchardia multiflora	perennial herb-geophyte	–	≥	–	–
Centrolepis aristata	annual herb	≥	≥	≥	≥
Chorizandra enodis	perennial herb	≥	≥	≥	≥
Chorizandra multiarticulata	perennial herb	–	≥	r	r
Cyathochaeta avenacea	perennial herb	±	≥	≥	–
Drosera glanduligera	annual herb	–	<	–	–
Drosera menziesii subsp. *menziesii*	perennial herb- geophyte	≥	±	≥	r
Goodenia micrantha	annual herb	r	r	r	≥
Hydrocotyle alata	annual herb	r	r	±	±
Isolepis cernua	annual herb	r	r	r	r
Kunzea micrantha subsp. *micrantha*	shrub	±	<	<	–
Lomandra spp.	perennial herb	–	≥	–	–
Meeboldina canus	perennial herb	–	≥	–	–
Mesomelaena tetragona	perennial herb	–	≥	–	–
Pimelea imbricata var. *major*	shrub	≥	–	r	≥
Philydrella drummondii	perennial herb-geophyte	≥	r	<	<
Schoenus odontocarpus	annual herb	r	r	r	r
Siloxerus humifusus	annual herb	–	r	–	r
Sowerbaea laxiflora	perennial herb-geophyte	<	–	±	±
Tribonanthes longipetala	perennial herb-geophyte	r	–	r	r
Utricularia violacea	perennial herb-geophyte	<	<	<	<
Verticordia densiflora	shrub	≥	≥	≥	±
Viminaria juncea	shrub	r	r	r	–

– not present in any plots before or after treatment, ≥ maintained or increased cover class in all plots it was present in, ± decreased in cover class in some and increased in others following treatment, < decreased cover class in all plots it was present in, r new recruit in plots in 2001.

decreasing in others, indicating that factors apart from herbicide application were impacting on the growth of the plants.

With annual taxa in particular, it is difficult to determine if change in cover over two years is seasonally related or treatment related. Of the eight annual species present all but one maintained or increased in cover and this at least indicated that the herbicide treatments were not adversely affecting those species. Changes in cover of perennial herbs, geophytes in particular could also be seasonally related. *Utricularia violacea*, for example, disappeared from all plots it occurred in including controls. Trials were scored almost a month later in 2001 and this wetland perennial geophyte had probably died back to its bulb. However the geophytes *Philydrella drummondii* and *Sowerbaea laxiflora* both appear to have been adversely affected by the metsulfuron methyl (2.5 g ha^{-1}) and chlorsulfuron treatments and the impacts of these herbicides on these species requires further investigation.

Although the data is limited and difficult to interpret due to seasonal effects, there are indications that *S. bulbifera* can be effectively controlled without impacting on a range of co-occurring native taxa present at the study site. Given the high flora conservation values of these wetlands this is an area worthy of further investigation.

An integrated approach

Importantly, chemical control techniques are only one part of an effective strategy for managing the spread of weeds such as *S. bulbifera* into relatively undisturbed bushland. For the last three years bush regenerators have been employed through September/October in the wetlands to manually remove small isolated populations in undisturbed areas. The wetland soils are still soft in early spring and entire plants including corms come out quickly and easily with minimal soil disturbance. At the same time a spray contractor with a knowledge of the flora and a background in bushland work has carried out chemical control on heavier infestations of *S. bulbifera* in more disturbed areas.

Effectiveness of the project over the three years has been reliant on workers having an understanding of the distribution of *S. bulbifera* across the Brixton Street Wetlands. The populations were mapped at the start of the project, in 1998. The maps helped set priorities and allowed for a carefully targeted works program revisiting small isolated populations over a number of years. The maps also allowed accurately recorded work to be carried out over time and provided some information on the effectiveness of the management strategy.

A detailed understanding of the reproductive biology and the mechanisms for dispersal of *S. bulbifera* is also an important part of any effective management strategy. The observation that most seed of *S. bulbifera* germinates the season after ripening and is relatively short lived in the soil imply that once the adult population has been controlled follow up work could be over in a three to five years. Workers in South Africa have found that among natural populations with in the Cape Region of South Africa, the seeds of most geophytes do not display dormancy, generally germinating the season after ripening (Keely and Bond 1997).

Although observations indicate that water flow plays a major role in dispersal, fire also probably facilitates the spread of *S. bulbifera* in the wetland. Bond and van Wilgen (1996) noted that South African geophytes that occurred in the fire prone environment of the Cape Region of South Africa were well adapted to surviving summer fires. Soil offers very effective insulation to the summer dormant corms and some have contractile roots that pull the storage organs of young plants deeper into the soil helping them avoid lethal fire temperatures. Fire can break down bulb dormancy in some South African geophytes (Pearce 1963) and can stimulate flowering followed by prolific seed production in others (Goldblatt 1978, Richardson 1984, Le Maitre and Brown 1992). The post fire environment then offers space and light where seeds can germinate and seedlings can establish in the absence of larger trees and shrubs (Goldblatt and Manning 1998). Keeping frequent fire out of the wetlands is probably quite important in preventing further spread of *S. bulbifera*.

Weed control is a part of an overall site restoration program at Brixton Street. The protection of native plant communities is the focus rather than simple elimination of the weed. Species moving into the gap created as *S. bulbifera* is removed will need to be carefully monitored.

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Appendix B: Transect monitoring score sheet

Transect monitoring score sheet

Location__________________________(for location within bushland draw simple mud map on reverse)

Date______________ Photo point No.__________ Transect No.__________ Quadrat No.________

Vegetation /Floristic Community ____

Soil ____

Weed species_____________________ Count (mature)_______ (juvenile)_______ % cover score_______

	Lifeform	Species	% cover class	Species	% cover class
Natives	Grasses				
	Herbs				
	Shrubs				

Weeds	Grasses				
	Herbs				
	Shrubs				
Weed summary		Perennial weedy grasses		Annual herbaceous weeds	
		Annual weedy grasses		Perennial herbaceous weeds	
		Weedy geophytes (bulbs ect)		Woody weeds	
		Bare Ground			

Braun-Blanquet Cover Classes <1% (**1**); 1 – 5% (**2**); 6 – 25% (**3**); 26 – 50% (**4**); 51 – 75% (**5**); 76 – 100% (**6**)