Project Plan

Does the chemical control of St John’s Wort provide positive biodiversity outcomes?

Significance of St John’s wort as an environmental weed and the non-target impacts of fluroxpyr herbicide application

**Research Project**

## Project Details

Project Name: Does the chemical control of St John’s wort provide positive biodiversity outcomes?

Funding: 2014-18 NES Plan appropriation

NES Plan recurrent

Project Manager: *Richard Milner (PCS)*

Project team members: Ros Ransome (PCS)

Clare McInnes (PCS)

Scott Seymour (PCS)

Steve Taylor (PCS)

Melita Milner (PCS)

Greg Baines (CR)

Brett Howland (NRM Programs)

Annabel Smith (University of Dublin)

Nicki Taws (Greening Australia)

Relevant legislation: Commonwealth EPBC Act, Nature Conservation ACT

Related actions:

* Molonglo Valley Plan for the Protection of Matters of National Environmental Significance (NES Plan): Action 6, 10, 13, 15, 26, 32, 38 and 42
* draft Molongo River Reserve Management Plan 2014-24: Objective 5 and 6
* ACT Weeds Strategy 2009-2019. Objective 2.4 and 3.2
* Canberra Nature Park Management Plan 1999: Actions 3.3.8 (b, g, i, and k), 3.4.1 (b), 5.1.8 (e), 5.6.2 (e).
* Action Plan No. 28 – ACT Lowland Native Grassland Conservation Strategy: Actions: 1 (a and e) and 5b (ii, iii, iv and vi)
* ACT Nature Conservation Strategy 2013-23: Strategy 1, 2, 3 and 4
* National Recovery Plan for Natural Temperate Grassland of the Southern Tablelands (NSW and ACT): An Endangered Ecological Community: Action 4.4.2

## Document location: [Project Plan STJW herbicide study\_v4.docx](file:///C:\Users\richard%20milner\AppData\Local\Microsoft\Windows\Temporary%20Internet%20Files\Content.Outlook\KUHS41SX\Project%20Plan%20STJW%20herbicide%20study_v4.docx)

## Circulation

## This draft Plan has been circulated to the following sections for information and comment:

|  |  |  |
| --- | --- | --- |
|  | **Date forwarded** | **Response received** |
| Finance Unit |  |  |
| PCS Fire Management Unit | 16/08/17 | No comment |
| PCS Healthy Country Team | NA |  |
| PCS Conservation Planning | NA |  |
| PCS Parks and Partnerships | NA |  |
| PCS District (project specific) | 16/08/17 | 19/08/17 |
| PCS Biosecurity and Rural Services | 09/08/17 | 10/08/17 |
| Conservation Research | 16/08/17 | 29/08/17 |
| Conservator Liaison Officer | 16/08/17 | No comment |
| Natural Resource Management Programs | 09/08/17 | 09/08/17 |
| Heritage Unit | NA |  |
| Procurement Capital Works | NA |  |

## Amendment History

| Version no. | Issue date | Amendment details | Author |
| --- | --- | --- | --- |
| 1.0 | 08/08/17 |  | Richard Milner |
| 2.0 | 15/08/17 | Comments from Taylor, Howland and Ransome incorporated. | Richard Milner |
| 3.0 | 05/09/17 | Comments from Kitchin, Brawata, Daines, Seymour, Sweaney, Roso and Smith incorporated. | Richard Milner |
| 4.0 | 11/10/17 | Comments from Smith incorporated | Richard Milner |

Procurement Capital Works Involvement

Is an exemption required to procure this project without Procurement and Capital Works (PCW) involvement? Yes

Reason for Exemption (if required):

Example:

* The project does not involve complex construction and consequently considered to have low risk in terms of WH&S
* The project proposes to manage these low risks by the application of ACT WH&S Guidelines directly by the PCS project manager. Contractors will be required to provide Safe Work Method Statements (SWMS) and submit monthly WHS Checklists in accordance with the ACT Gov WHS policy for construction
* Simple procurement
* Project team experienced in ACT Government procurement processes

Project Plan Approval

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Daniel Iglesias, Director, Parks and Conservation Services

Date:

# 

# Background

Invasive weeds pose a significant threat to biodiversity conservation worldwide (Saka et al. 2000). They have the potential to displace native plant species; change plant community composition and alter ecosystem processes, including disturbance regimes (e.g. grazing and fire) and even nutrient cycling (Ehrenfeld 2003; Yurkonis *et al.* 2005). Weed invasion has been linked to the extinction of a number of rare and endemic plant species and continues to be a key threat for the conservation of numerous other rare and threatened plant species (Briggs and Leigh 1996).

Given the considerable threat invasive weeds pose to biodiversity - significant effort and money is placed into the control and management of weeds worldwide. While the overarching objectives of these control programs are generally to conserve biodiversity – rarely is a biodiversity response quantified. Rather the success of weed control programs is commonly measured by the response of the target weed species and whether it is killed or contained (Kettenring and Adams 2009; Lindenmayer et al. 2017). This is an important distinction as despite the considerable amount of research and resources invested in invasive species control, there are relatively few examples of weed control studies demonstrating positive localised biodiversity outcomes (Downey et al. 2009; Kettenring and Adams 2011; but see Hui and Richardson 2017) and in many circumstances such programs show either neutral or negative localised impacts (Myers et al. 2000; Rinella et al. 2009; Skurski et al. 2013). However, it is important to acknowledge that while localised impacts to biodiversity may not always be positive - controlling the further spread of weeds can have significant landscape conservation benefits (Hui and Richardson 2017).

Herbicide application is considered the most economical and effective method for controlling invasive weeds and is by far the most commonly utilised control method worldwide. While the intended use of herbicide to control weeds and conserve biodiversity is valid, the application of herbicide can have significant ecological implications. For instance, herbicide application has been shown to significantly impact native plant species richness and community composition (Crone et al. 2009; Power et al. 2009), native seed germination and seedling establishment (Rokich et al. 2009; Wagner and Nelson 2014), native plant survival, flowering and seed production (Rice et al 1997; Schmitz et al. 2014; Crone et al. 2009), soil microbial communities (Druille et al. 2016), terrestrial invertebrates and fauna assemblages (Sullivan et al. 1997; Haughton et al. 1999), aquatic communities (Relyea 2005) and the invasibility of ecosystems through the reduction in resource competition (Thompson et al. 2001). These risks are exacerbated where threatened species occur and there are examples of herbicide application impacting significantly on endangered species (Matarczyk et al. 2002). It is therefore essential that the ecological risks of using herbicide are better understood and that these risks are weighed against the impacts of the weeds themselves (Skurski et al 2013).

Across south-eastern Australia, St John’s wort is considered a major weed of grassy woodland ecosystems and agriculture (Buckley et al 2003). It is toxic to stock, competes with pasture species and reduces property values. It is also believed to outcompete native species and increase the invasibility of grasslands (pers. comms. Richardson 2017), however relatively little is known about what drives it occurrence. In the ACT St John’s Wort is listed as a declared pest plant (level 3; i.e. must be suppressed), due largely to its significance as an agricultural weed, and must therefore be controlled. While St John’s Wort is considered to impact significantly on native species diversity and composition, there is little quantitative evidence to support this. Despite this, significant effort and money is dedicated to the control of this species. In 2016/17, 2673 ha of St John’s Wort was sprayed across numerous nature reserves where biodiversity conservation is a priority. This lack of knowledge regarding the impacts of St John’s Wort on native species biodiversity is of significant concern as the non-target impacts associated with control strategies (i.e. herbicide application) needs to be weighed up against the impacts of the weed species itself.

St John’s wort is typically controlled in the ACT through spot spraying or boom spraying using the chemical fluroxypyr. Fluroxypyr is considered a narrow-spectrum broad-leaved herbicide that does not kill grasses and will only impact some species of native forbs (ACT Government 2011). However, there are no quantitative studies that demonstrate the limited impacts of fluroxpyr on native non-target species and there is growing concern that the application of herbicide to control this species is doing more damage than the species itself.

# Objective

The objectives of this study are to:

1. Quantify the impacts of St John’s wort on native lowland grassy woodland communities, including native plant species diversity and community composition.
2. Determine the potential drivers of St John’s Wort occurrence.
3. Determine the non-target impacts of fluroxpyr herbicide application, to control St John ’s Wort, on native lowland grassy woodland communities, including native plant species diversity and community composition.
4. Compare non-target impacts of different herbicide application methods (incl. application rate and droplet size) on native plant species diversity and community composition.
5. Determine the impacts of herbicide application on native seed production and viability.
6. Compare the impacts of St John’s wort with the non-target impacts of St John’s wort control.

# 

# Outcomes

* Improved knowledge and information relating to the impacts of St John’s wort on native lowland grassy woodland communities. If the impact is small or neutral, significant resources could be saved by scaling back herbicide application, with potential positive broader biodiversity outcomes.
* Information on potential drivers of St John’s Wort occurrence, which can be used to implement pre-emptive management in areas where St John’s Wort is absent or densities are still low and in areas where it is likely to pose a significant threat to biodiversity.
* Improved knowledge and understanding of the non-target impacts of St John’s wort control using different fluroxpyr application methods in native lowland grassy woodland communities.
* Improved knowledge about the management of box-gum woodland and natural temperate grassland.
* Contribute towards the adaptive management of Box-gum woodland and natural temperate grassland within the Molonglo River Reserve and associated offsets to maintain and enhance ecological condition.

# Output(s)

* Research manuscript on the significance of St John’s wort as an environmental weed and the non-target impacts of its control.
* Input into the eWOP
* Input into Molonglo River Reserve and CNP Operational Plans.
* Inclusion of research results in NES Plan Annual report to Commonwealth
* Cost benefit analysis for St John’s wort control

# Scope of Work

*Study design*

The study design consists of four components. The first component looks at the significance of St John’s Wort as an environmental weed and what the potential drivers of its occurrence are. Depending on the outcomes of component 1, it is possible that the off-target impacts of controlling the species using herbicides may outweigh the impacts of St John’s Wort itself. The second component of the study will quantify off-target herbicide movement (i.e. drift) for three herbicide application methods. The results from this component will be used to calibrate herbicide application rates used in components 3 and 4 to test the non-target impact of St John’s Wort chemical control on native species diversity, abundance, composition (Component 3) and native seed production and viability (Component 4).

*- Component 1: Impacts of St John’s wort on native plant species diversity and community composition.*

Data collection for component 1 is complete. Floristic surveys were undertaken across six hundred 1m quadrats randomly placed across four ACT grassland reserves (Gungaderra, Mulanggari, Dunlop and Jerrabomberra West) between September and November in 2015 and 2016 as part of a larger grassland restoration research program. All observable plant species within the 1 m quadrates were recorded, counted and assigned a percentage cover score to the nearest 10%.

Hierarchical linear mixed models will be used to evaluate the relationship between cover and diversity of native species, native and exotic functional species groups, and indicator species with the occurrence and abundance of St John’s wort (Model 1 = Species richness ~ STJ presence/absence; Model 2 = Species richness ~ STJ abundance) with soil, elevation, topography, vegetation structure and % cover of C3 grasses included as environmental variables. These same environmental variables will also be used to run a species distribution model for St john’s wort,(Model 3= STJ pres/abs ~ environment; Model 4 = STJ abundance ~ environment) to understand potential drivers of St John’s wort occurrence.

*- Component 2:* *Quantifying off-target herbicide movement for three herbicide application methods.*

Off- target herbicide movement is primarily influenced by the volatility of the herbicide, weather, equipment and droplet size. Through carefully considering and managing for these factors we are better able to reduce the risks of off-target herbicide movement.

Component 2 will provide the background information necessary for Component 3 (i.e. to determine the non-target impacts of St John’s Wort control). Spray distribution and droplet density at ground level will be compared between three commonly used herbicide application methods and concentration rates in Kama Nature Reserve in late November 2017:

1. Spot spraying with quick spray unit and spray lance

- Starane Advanced (*fluroxypyr*) 300ml per 100L water plus Uptake Oil 500ml per 100L water.

- Spot spraying is considered the most ecologically sensitive method of herbicide application due to the operator’s ability to specifically target weed plants. However, herbicide application rate is not set and therefore operators can easily over apply herbicide.

1. Boom spraying – coarse droplet - flat pen nossel at 90o

- Starane Advanced (*fluroxypyr*) 1.8L/ha, water 100L/ha and Uptake Oil 500ml per 100L water.

- Course droplet size reduces the risk of spray drift via wind but increases the risk of spray drift via gravity and therefore may increase the risk of droplets reaching non-target plants that occur directly below St John’s wort.

1. Boom spraying – fine droplet - twin bodied nossel at 60o

- Starane Advanced (*fluroxypyr*) 1.8L/ha, water 75L/ha and Uptake Oil 500ml per 100L water.

- Finer droplet size can increase the risk of spray drift via wind but reduce the risk of spray drift via gravity and therefore may reduce the risk of droplets reaching non-target plants that occur directly below St John’s wort.

To quantify off-target herbicide movement for each of the herbicide application methods, droplet density and spray distribution will be measured using water sensitive paper positioned 20cm above ground level. Ten water sensitive cards will be used per herbicide application method (i.e. n=30). Five will be placed in patches of moderate-high density St John’s wort (treatments) and five will be placed in grassland patches with no St John’s wort (controls). Herbicide will be applied using to the above methods.

Droplet densities and spray distribution will be assessed using an automated image analyser (e.g. Photoshop). Results will be compared between control and treatment types and used to determine quantity of off-target herbicide movement per herbicide application method. Results will be used in Component 3 of the study.

*- Component 3***:** *Non-target impacts of St John’s wort chemical control on native plant species diversity and community composition.*

Component 3 will commence in Spring 2017 and continue to Spring 2019. The study will be undertaken in Jerrabomberra West Nature Reserve, Kama Nature Reserve (woodland section) and Mulangarri Nature Reserve. Each of the Nature Reserves supports a high diversity of native forb and grass species. While St John’s wort is present in each of the reserve, there is no known history of boom spraying at the proposed study sites.

A statistical power analysis was performed for sample size estimation using data from the *PCS Grassland restoration* researchprogram. The projected sample size required was approximately *N*= 16 with effect size = 0.80, alpha = 0.05 and power = 0.80.

We will establish 8 replicate sites (separated by a minimum of 100m) per reserve (*n*=24) within patches of forb rich native grassland (Figure 1) with **NO** St John’s Wort. At each site we will establish three 2 x 2 m plots, consisting of a 1 x 1m core with a 0.5 m buffer: *control, low concentration rate* (Treatment 1) and *high concentration rate* (Treatment 2; Figure1). Each plot will be positioned so that it contains in the core area a group of native species or families, with characteristics that may be affected by Fluroxypyr: *Eryngium ovatum* (Apiacea), *Chrysocephalum apiculatum (*Asteraceae)*, Arthropodium species* (Asparagaceae), *Wurmbea dioica* (Colochicaceae), *Lomandra species* (Asparagacae)*, Desmodium and/or Glycine species* (Fabaceae)*, Plantago varians* (Plantaginaceae)*, Tricoryne elatior* (Hemerocallidaceae)and *Triptilodiscus pygmaeus* (Asteraceae)*.* Treatments will be randomly assigned within the site and arranged so that plot boundaries do not overlap.

Fluroxypyr will be applied to *Low concentration rate* and *High concentration rate* treatments in early Summer 2017 on a windless day. Herbicide spray rate for each of the treatments will be determined by the highest and lowest quantity of off-target herbicide movement measured in Component 2. Herbicide will be applied to the entire 2 x 2m plot area using a handheld pressure sprayer. No herbicide will be applied to the control. A screen will be placed between control plots and treatment plots to reduce the risk of spray drift.

Pre- (November 2017) and post- (November 2018 and 2019) treatment floristic surveys will be undertaken across all plots. All observable plant species within the 1 x 1m core area will be recorded, counted and assigned a percentage cover score to the nearest 10%.

Figure 1. Experimental design.

*Statistical analysis*

Generalised linear mixed models will be used to analyse the effect of herbicide application on grassland species richness and individual species abundance. Ordination analyses, such as multi-dimensional scaling (MDS), will be used to visually assess the similarities and differences in plant community composition between the treatment and control plots. We will also analyse MDS axes in linear models to determine the statistical effect of herbicide application on plant community composition.

*- Component 4***:**  *Non-target impacts of St John’s wort control on native seed production and viability.*

We will assess the medium term (i.e. 12 months after spraying) effects of fluroxypyr concentration rate on flower production and seed viability for the same native forb species used to define plot location in Component 3. Number of flowers or flower heads (i.e. for Asteraceae) per plant will be counted within the 1 x 1m core area for each treatment type (i.e. *control, low concentration rate* and *high concentration rate*) across 7 of the 15 replicate sites in Spring 2018. Seed will be harvested at maturity from each of the native species. Seed germination tests will be performed using a consistent weight/quantity of seed for each species. Greening Australia will be engaged to collect the seed and run the seed viability tests.

Reporting

Following the completion of data collection, PCS will prepare in collaboration with the University of Canberra or ANU a joint research manuscript for publication in a peer reviewed scientific journal (June 2020) as well as a paper for the CAWS biennial conference (2020). The research results will also be incorporated into the eWOP, Reserve Operational Plans and the NES Plan Annual report to the Commonwealth.

# 

# Assumptions and Constraints

*Study site selection*

Specific study site locations have not been finalised. This needs to be undertaken in spring when the distribution and occurrence of native forbs and St John’s wort is clear. Furthermore, the number of replicates has not been finalised as this will be dependent on finding a suitable number of study sites that satisfy key criteria; known spray history, dominated by native species with high native forb diversity and presence of specific native forb species.

*Weather*

Climatic conditions leading up to the survey period (Spring/early Summer) will influence treatment response strength. For example, treatment responses may be reduced or not detectable following extended periods without rain.

# 

# Budget

Funding for year 1 (2017/18) of the project will come from the 2014-18 NES Plan appropriation and funding for year 2 (2018/19) and 3 (2019/20) will come from the Molonglo NES Plan recurrent budget.

The total required for the study is $23,000 GST Exclusive over 3 years.

|  |  |  |  |
| --- | --- | --- | --- |
| **Item** | **2017/18** | **2018/19** | **2019/20** |
|  | GST Exclusive | GST Exclusive | GST Exclusive |
| Component 1 – Statistical analysis | 1000 | 0 | 0 |
| Component 2 – Herbicide application + materials | 1500 | 0 | 0 |
| Component 3 – Floristic surveys | 2000 | 2000 | 1500 |
| Component 3 – Herbicide application + materials | 500 | 0 | 0 |
| Component 3 – Data entry | 500 | 1000 | 500 |
| Component 4 – Seed collection and seed viability tests | 0 | 5000 | 0 |
| Statistical analysis | 0 | 0 | 1000 |
| Honours scholarship or scientific manuscript preparation | 0 | 5000 | 0 |
| Contingency | 500 | 1000 | 0 |
| **Total budget** | **6000** | **14000** | **3000** |

# Stakeholders

Parks and Conservation Service

- PCS Projects (Richard Milner and Ros Ransome)

- Biosecurity and Rural Services (Steve Taylor)

- Environmental Offsets (Clare McInnes, Sophia Callander and Melita Milner)

- Urban Reserves (Scott Seymour and Maree Gilbert)

- National Parks and Catchments (Darren Rosso)

Natural Conservation Policy

- Conservation Research (Greg Baines)

- NRM Programs (Brett Howland)

J & J French Agriculture (Jack French)

Greening Australia (Nicki Taws)

University of Canberra or Australian National University TBC

University of Dublin (Annabel Smith)

# 

# Risk Management

The key risks to the successful delivery of project Outcomes and Outputs are:

|  |  |
| --- | --- |
| ***Major risks include*** | ***Strategies in place to treat against the above risks include*** |
| 1.     Failure by contractor to deliver as specified | * Rigorous evaluation criteria used in tender process. * Quality requirements and standards specified. * Undertake regular inspections during works. |
| 3.     Weather | * Allow for wet days in contract. * Allow days for unfavourable weather conditions. |
| 4.    Lack of stakeholder support | * Conduct appropriate consultation with stakeholders in planning stages of the project. * Regular updates and information to key stakeholders such as PCS land manage on project progress and schedule. |
| 5.     Project delays | * Prevention – good project management to ensure project schedule is maintained |
| 6. Budget insufficient/ overspend | * Prevention – cost estimates at key stages, sound procurement processes. * Good management of change requests when in contract. * Adequate contingency appropriate to the risk level. |

**General risk management strategies**

* A more detailed Risk Plan is to be developed for each procurement.
* Ongoing risk management via a dynamic risk register to assess and managing new risks as they arise
* Ongoing risk identification and mitigation strategies as project progresses.
* Alerting Manager early of potential risks and possible mitigation strategies

# Schedule

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Financial year** | **2017/18** | | | | | | |  | **2018/19** | | | | | | | | | | |  | **2019/20** | | | | | |
| **Milestones** | Aug-17 | Sept-17 | Oct-17 | Nov-17 | Dec-17 | Jan-18 | Feb-18 |  | Aug-18 | Sep-18 | Oct-18 | Nov-18 | Dec-18 | Jan-19 | Feb-19 | Mar -16 | Apr-19 | May-19 | Jun-19 |  | Oct-19 | Nov-19 | Dec-19 | Jan-20 | Feb-20 | Mar -20 |
| On-ground works |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Component 1 – Statistical analysis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Component 2 – Quantify off-target herbicide movement |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Component 3 – Floristic surveys |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Component 3 – Herbicide application |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Component 3 – Data entry |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Component 4 – Seed collection |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Component 4– Seed viability tests |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Honours student engaged |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Reporting |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Statistical analysis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Scientific manuscript |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

References

ACT Government 2011. Invasive weed management guidelines.

Buckley Y. M., Briese D. T. And Rees M. 2003. Demography and management of the invasive plant species *Hypericum perforatum.* I. Using multi-level mixed-effects models for characterizing growth, survival and fecundity in a long-term data set. Journal of Applied Ecology 40, 481-493.

Crone E. E., Marler M. and Pearson D. E. 2009. Non-target effects of broadleaf herbicide on a native perennial forb: a demographic framework for assessing and minimizing impacts. Jounral of Applied Ecology 46, 673-682.

Downey P. O., Williams M. C., Whiffen L. K., Turner P. J., Burley A. L. and Hamilton M. A. Weeds and biodiversity conservation: A review of managing weeds under the New South Wales Threatened Species Conservation Act 1995. Ecologcial Management and Resetoration 10, S53-S58.

Druille M., Garcia-Parisi P. A., Golluscio R. A., Cavagnaro F.P. and Omacini M. 2016. Agriculture, Ecosystems and Environment 230, 184-190.

Ehrenfeld J. G. 2003. Effect of exotic plant invasions on soil cycling processes. Ecosystems 6, 503-523.

Haughton A. J. , Bell J. R., Boatman N. D. and Wilcox A. 1999. The effects of different rates of the herbicide glyphosate on spiders in arable field margins. The Journal of Arachnology 27, 249-254.

Hui C. and Richardson D. M. 2017. Invasion Dynamics. Oxford University Press.

Kettenring K. M., Adams C. R. 2009. Lessons learned from invasive plant control experiments: a systematic review and meta-anylsis. Journal of Applied Ecology 48, 970-979.

Lindenmayer D. B., Wood J., MacGregor C., Hobbs R. J. And Catford J. A. 2017. Non-target impacts of weed control on birds, mammals, and reptiles. Ecosphere 8, 1-19.

Myers J. H., Simberloff D., Kuris A. M. and Carey J. R. 2000. Eradication revisited: dealing with exotic species. Trends in Ecology and Evolution 15, 316-320.

Power E. F. , Kelly D. L. and Stout J. C. 2009. The impacts of traditional and novel herbicide application methods on target plants, non-target plants and production in intensive grasslands. Weed Research. DOI: 10.1111/wre.12009

Relyea R. A. 2005. The lethal ipact of Roundup on aquatic and terrestrial amphibians. Ecological Applicaitons 15, 1118-1124.

Rice P. M., Toney C., Bedunah D. J. and Carlson C. E. 1997. Plant community diversity and growth form responses to herbicide applications for control of *Centaurea maculosa*. Journal of Applied Ecology 34, 1397-1412.

Rinella M. J., Maxwell B. D., Fay P. K. Weaver T and Sheley R. L. 2009. Control effort exacerbates invasive-species problem. Ecological Applications 19, 155-162.

Rokich D. P., Harma J., Turner S. R., Sadler R. J. And Tan B. H. 2009. Fluazifop-p-butyl herbicide: implications for germination, emergence and growth of Australian plant species. Biological Conservation 142, 850-869.

Sala, O. E., et al. 2000. Biodiversity – Global biodiversity scenarios for the year 2100. Science 287, 1770 – 1774.

Schmitz J., Schafer K. and Bruhl C. A. 2014. Agrochemicals in field margins – Field evaluation of plant reproduction effects. Agriculture, Ecosystems and Environment 189, 82-91.

Skurski T. C., Maxwell B. D. and Rew L. J. 2013. Ecological tradeoffs in non-native plant management. Biological Conservation 159, 292-302.

Sullivan T. P., Sullivan D. S., Lautenschlager R. A. and Wagner R. G. 1997. Long-term influence of glyphosate herbicide on demosgraphy and diversity of small mammal communities in coastal coniferous forest. Northwest Science 71, 6-17.

Thompson, K., Hodgson, J.G., Grime, J.P and Burke, M.J.W. 2001. Plant traits and temporal scale: evidence from a 5 year invasion experiment yusing native species. Journal of Ecology , 89, 1054-1060.

Wagner V. and Nelson C. R. 2014. Herbicides can negatively affect seed performance in native plants. Restoration Ecology 22, 288-291.

Yurkonis K. A., Meiners S. J. and Wachholder B. E. 2005. Invasion impacts diversity through altered community dynamics. Journal of Ecology 93, 1053-1061.