Thermal weed control to remove off target toxicology risks.

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Introduction

Conservation efforts are directed at preserving and restoring habitat for flora and fauna in order to prevent extinction, support biodiversity and maintain essential ecosystems.

In Australia conservation efforts are not always working. Biologists agree that amphibians are currently the most susceptible species to the sixth mass extinction in the world's history (McCallum, 2007) including being the most susceptible group to climate change. Our statistics in Australia are not looking good.

In the first 200 years of European occupation in Australia, no frog species became extinct despite the huge losses of mammal species. Australia accounts for over 40% of the world's mammalian extinctions since about 1800 (Australian Bureau of Statistics, 2012). Only 34 species of amphibian are reported to have become extinct since 1500 worldwide, but there is strong evidence that this situation is worsening, because nine of these extinctions have taken place since 1980. Australia and New Zealand have significantly more enigmatic-decline species than the average for amphibians as a whole (Stuart et al, 2004). Australia lost four frog species in one decade alone.

Most parts of the Australian landscapes are at risk of invasion by one or more species of non-native plants (Grice, 2006) and weed control forms a major part of conservation and bush regeneration works. "Conventional" weed control in bush regeneration started with the Bradley Method in 1960s finding remnant bush removing weeds manually starting from the least weed invaded areas and working towards the edges. It was largely done without the use of herbicides. Since the 1980's revegetation weed management has been dominated with herbicide application, predominantly glyphosate products, following the controversial Wingham Brush method being introduced (Stockard, 1996). The use of glysophate at the Wingham Brush site was hotly debated at the time, with such a major shift away from the Bradley method. Glyphosate (the active constituent in Roundup) is no longer seen as "controversial" particularly due to its promotion as a "safe and inert" herbicide. Friends of the Earth (Winer, 2014) state that it is now the world's most used chemical at 650,000 tonnes in 2011 and estimated to increase by 800% by 2025.

Mesnage et al, 2014 (Winer, 2014) states that Roundup has been shown to be 125 times more toxic to humans than its glyphosate active principle.

The Department of Environment and Climate Change (NSW) 2007, Management Plan for the Green and Golden Bell Frog Key Population at Kurnell, teaches that glyphosate compounds have been found to be acutely toxic to the Western Bell Frog *Litoria moorei* and may be toxic to other frog species, and Biactive® formulations are not necessarily less toxic to frogs.

The off target toxicology risks of using herbicides for amphibians, our most vulnerable genera, cannot be ignored, in both wetland and terrestrial zones (frogs are terrestrial as well as aquatic fauna).

In this paper the reader is provided with a brief overview of the non chemical weed management apparatus which have become available in the last five years, and introduces the applicability of these techniques to conservation areas.

Two case studies are presented to demonstrate potential applicability to conservation practices.

Finally, there are some concluding remarks.

Thermal and mechanical weed management alternatives

Mechanical methods of weed control for paved surfaces include brushing, whipper-snipping (weed whacking/ brush cutting), hand weeding. Thermal weed control methods include flaming, hot air, radiant heat, hot water, hot foam and saturated steam.

Mechanical

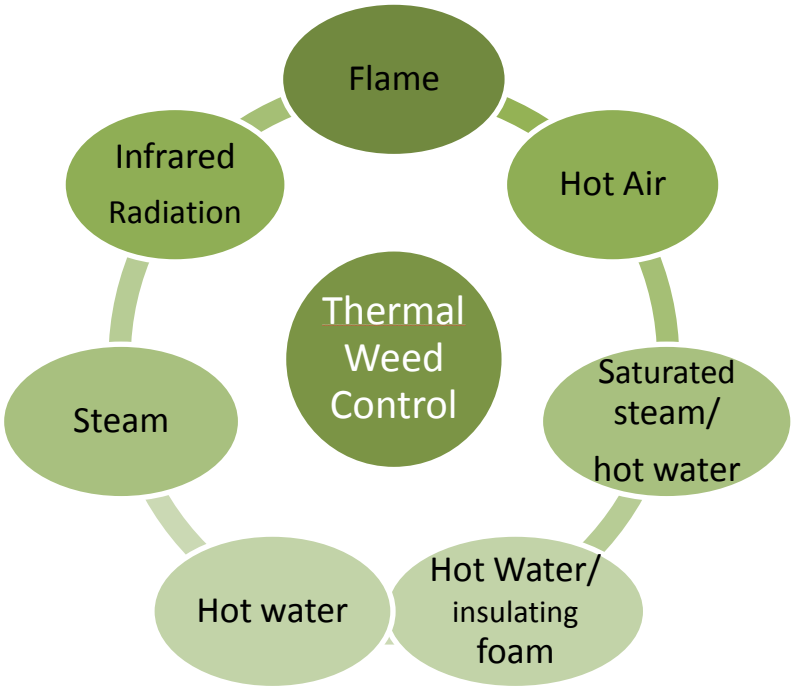
Weed brushes are a specialist piece of equipment mounted to mobile plant produced by companies that specialize in cleaning apparatus such as Karcher, Nilfisk, Koti, Kersten, Ecobrush, Weedbrush. Whipper Snippers are manually operated hand held units which are readily available from grounds and garden care outlets. Mechanical weed control has the disadvantage of removing the above ground parts of weed only. Weeds by their nature are adapted to grazing and regenerate quickly from the meristematic cells at the plants crown or from the apical cells of leaves and shoots. Mechanical weed control also has been shown to damage assets, brushes causing additional wear and tear on paved surfaces (Lefevre et al 2001; Wood, 2004) and potentially damage tree assets eg whipper snipper girdling of trunks.

Thermal

In the last 10 years there has been significant development of a number of varieties of thermal weed control.

Earliest documented patents for thermal weed control date back to the 1920's when steam trains in Australia were fitted with pipes to divert locomotive steam to distribution pipes directing hot water to vegetation growing on the rock ballast under the tracks. The advent of herbicides in the 1940's saw this technology almost disappear until the early 1990's when a mobile method and apparatus for controlling vegetation using hot water was patented (Newson R J, PCT/NZ93/00035). In the last 10 years there has been significant development of a number of varieties of thermal weed control.

Thermal weed control options can be broadly classed into two categories, **hot dry and hot wet.**



Hot Dry

Hot Dry includes flame, hot air and radiant heat. Flame and radiant heat tend to be more portable, use LPG / propane but do not penetrate into the crown of the plants efficiently, often requiring more frequent interventions. Exposed flame weeders pose significant fire risk in dry conditions and on mulches, and cannot be used on rubber soft fall, rubber paving, near litter, debris or irrigation lines and fittings.

Hot air weed control extracts hot air from a flame source directing it onto vegetation such as the Zacho: Turbo Weed Blaster. Hot air has very high energy consumption. Radiant Flame units direct flame heat, under the protection of a shroud, onto a ceramic or metal surface in close to proximity of vegetation. Units can be hand held, trolley or vehicle mounted available from HOAF NL, Sunburst OR, USA. Hand held LPG/ propane flame burners are an often used alternative, mainly for small or difficult to access areas.

Hot Wet

Hot wet weed control apparatus are mainly of the hot water, hot foam and saturated steam embodiments. Wet steam, such as the Canadian Greensteam ® (no longer in production) and HOAF 'greensteam' overcome some of the fire risk of open flame but produce too little volume of wet stream to provide commercial viability (Authors personal experience). The superior control of weeds by hot wet methods over hot dry is due to moisture enabling more rapid transfer of lethal heat into cell structure than dry heat. Deeper penetration into meristematic cells is experienced and residual heat in the surface soil is enough to provide some control of seed bank. (Hansson & Ascard 2004, Kristoffersen et al 2007).

There have been improved methods of heating water by a number of manufacturers in Europe, USA and Australia. Development of hydraulic controlled machine mounted applicator heads by Wave NL in the Netherlands and Empas Gmbh increases speed and area of application in accessible open paved areas such as parks, footpaths, streets and lanes. Use of infra-red weed detection by Wave NL reduces water and energy consumption. Heated foam, formed by mixing a heated aqueous solution of water, surfactant and hot air, first

patented in 1995 (Rajamannan A.H.J US5,575,111 Filed 28 Sept,1995) has been further developed by Weeding Technologies Ltd, GB. Heated foam has been demonstrated to expose plant tissue to heat for a longer period increasing efficacy when compared to hot water. Saturated steam, created by increasing the boiling point of heated water under pressure to approximately 115 - 120C and then depressurising in a depressurising nozzle assembly in close proximity to vegetation delivers a mixture of saturated steam and hot water at 100C to the weeds. (Aus Patent 2004320467 P.Musten, D.Parkin, J.Winer).

Case Study - Boral Northern Grasslands

Since 2013 Aus Eco Solutions have implemented the environmental management plan developed by Brett Lane and Associates, aimed at the conservation and improvement of a 95-hectare native grassland offset owned by the Boral Property Group, known as the Northern Grasslands. The site harbors one Critically Endangered species, the Spiny Rice-flower, *Pimelea spinescencs*, listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act 1999) and one threatened species, the Striped Legless Lizard also listed under the EPBC Act 1999.

The Spiny Rice-flowers have been translocated into 9 fenced areas across the Northern Grassland site to limit herbivore predation from rabbits and sheep. Current management methods are strictly non-chemical due to their current EPBC Act 1999 listing. Historically, hand weeding and brush cutting were the only methods used to control the high threat weed species such as Serrated Tussock (*Nassella. Trichotoma*), Chilean Needle-grass (*Nassella nessiana*), Cane Needle-grass (*Nassella hyaline*), Artichoke Thistle (*Cirsium carduncul*us *subsp flavescens*) and Spear Thistle (*Cirsium vulgare*) within the pens.

These methods are time consuming and only act as a suppressant for the current weed populations and furthermore disturb the soil allowing for future weed species colonization. A study by J Matarczyk, A Willis, J Vranjic and J Ash (2002) was initiated after an accidental Glyphostae spray drift incident put a small population of the Spiked Rice-flower (*Pimelea spicata*) in danger of failing. Results from this investigations showed that seedlings and young plants where the tap root was undeveloped were killed by a single application of Glyphosate, while older more developed plants died back initially, although in time, 50% re-sprouted (Matarczyk, Willis, Vranjic & Ash 2002). Of the 50% of individuals that re-sprouted a significant decrease in tap root diameter was noted which implies that continued Glyphosate exposure would eventually kill the plants by impairing the potential for recovery (Matarczyk, Willis, Vranjic & Ash 2002). While this study was not conducted on the exact species of Pimelea located at the Northern Grasslands it does suggest that due to it being a member of the same Genus and being morphologically similar, results may be inferred.

Hydro thermal technology offers benefits of being a chemical free and minimal soil disturbance technique within these sensitive sites. To explore the potential benefits of this technology Aus Eco Solutions is utilising a SW800 steam weeder from Weedtechnics and is collecting data from a range of sites within the Northern Grasslands. Data collected will include weed density / diversity before and after each treatment, as well as recording any new native seed bank germination and any direct or indirect effects to the Spiny Rice-flower populations in general.

The experience of the authors when treating weeds utilising the SW800 in urban environments is an observed germination of a range of species in the weed seed bank. It is hypothesised that these seeds are located high in the soil profile, potentially just below the

surface or on the surface. We also expect that further study will demonstrate that the process of thermal shock (rapid increase in temperature from ambient to 98 - 100C) will either stratify the seed coat and assist in germination, denature the seed rendering it unviable or in some cases have no effect. The first two effects serve to deplete the seed bank initially and then further with subsequent follow-up treatments. We expect that being able to control the seed bank in the early stages of a project will greatly reduce the resources required for managing weeds as the project establishes.

We hypothesize that the hydrothermal technique will allow the more deeply germinating native seeds such as *Stipa bigeniculata* and *Themeda triandra*, which screw themselves deeper into the soil profile, to revegetate the Spiny Rice-flower sites adding to the conservation value of the site.

The future of conservation in Australia needs a wide range of weed management tools and techniques including non chemical methods to preserve, improve and stabilize the small pockets of pre European native remnant vegetation that still exists. Pilot programs such as these are needed to establish best practices and circulate the outcomes throughout the industry.

Case Study - Country Fire Authority Fiskville Training Facility Wetlands

Wetlands are formed by the interaction between terrestrial and aquatic systems and are defined by areas of periodic, permanent or intermittent inundation that hold still or very slow moving water which leads to the development of hydric soils (Department of Environment and Primary Industries 2014). These systems are amongst the world's most productive and complex environments. Constructed wetlands have been increasingly used worldwide for the treatment of stormwater and other waste water runoff. It is generally accepted that if carefully designed and well maintained, constructed wetlands can produce an effluent suitable for reuse and provide suitable habitat for wildlife at a relatively low cost.

Aus Eco Solutions undertook the recent landscaping works component as part of the construction of a wetlands at the CFA Training Facility at Fiskville. This included revegetating a diversion channel with a hydroseed native seed blend, planting 2000 plants in the terrestrial zones along the diversion channel, constructing a rabbit proof fence around the constructed wetlands and planting 10,000 plants in the constructed wetlands. The project included maintenance of the site for a two year period.

The design of the wetlands was prepared by landscape designer, Cardno, and civil construction firm, Bitu-mill, completed all associated earthworks to establish the wetlands. The landscape designs included all native species including the hydroseed blend.

The specifications stipulated the frequency of maintenance visits:

Months 1 - 2 Three visits per month

Months 3-6 Two visits per month

Months 7-24 One visit per month

Weed suppression was stipulated in the specifications, however no methods were stipulated. The methodology options that Aus Eco Solutions had to choose from at the time were hand-weeding, brush-cutting or using herbicide such as biactive glysophate herbicide. Due to the competitive nature of the bid and no specifications, Aus Eco Solutions based their bid on the using a combination of biactive glysophate herbicide and hand-weeding smaller weed infestations.

During the establishment component, the use of biactive glysophate herbicide was used to prepare the site for revegetation, particularly the diversion channel revegetation.

A few months into the maintenance phase of this project, Aus Eco Solutions became a licensee of the Weedtechnics saturated steam technology and decided to trial the use of the SW800 steam weeder at the site.

A number of benefits for adopting the technique have already emerged. The maintenance crews have found that saturated steam has provided more flexible working options such as working in wet or windy conditions. This site is a particularly susceptible to inclement weather so not having to factor weather into scheduling processes has been a major advantage.

The water levels within the wetlands can fluctuate making access to submerged weeds challenging. The maintenance crews have discovered that using the SW800 has allowed even submerged weeds to be effectively treated as the long handle enables weeds that would not have been treated previously to be reached.

There is no off target risk to tubestock planted during the revegetation component of the project. While all care is taken when using herbicides to undertake weed control around tubestock, there is always a risk of spray drift and is dependent on operator skill and attention.

The crews have found saturated steam to be significantly more efficient at tackling invading weed species than the alternative hand weeding. The time comparison is similar to that taken for herbicide spraying using Quikspray units or knapsacks with 1 to 3 seconds required of plant contact to explode the plant cells using the SW800.

The risk of water catchment contamination from herbicides has also been eliminated. The crews have observed an abundance of wildlife moving into the wetlands since their construction, particularly frogs and an array of water birds.

Recruitment of wetland plants has occurred rather than any losses. To date this has meant the none of the budget allocated to plant losses has had to used. Crews have observed that the number of wetland plants has been increasing naturally since the initial planting.

Overall, the maintenance component of this project is tracking ahead of budget with the number of saturated steam treatments required falling within the existing nominated treatment schedule within the specifications, no expenditure on herbicides and no expenditure on plant losses.

Results

In a growing number of countries use of glyphosate and other herbicides and pesticides have been regulated against. By example the EU Water Framework Directive (WFD) orders local authorities at water catchment level to reach a 'good quality' of the water by the end of 2015, which by definition requires mitigation of pesticide residues. The Netherlands after 10 years of research and trials has banned the use of herbicide at Municipality level from September 2015 (The Sustainable Pulse, 2014). Belgium has banned the use of pesticides by municipalities. Local authorities in Denmark have signed a voluntary agreement to totally phase out herbicides in urban areas. Switzerland has banned the use of herbicides on roofs, balconies, streets and squares. Ninety (90) provinces across Canada have banned the use of herbicides for amenity horticulture including vegetation management in streets and public open space. New York State has banned the use of all pesticides in schools, San Francisco has banned the use of herbicides in the catchment of the Bay area. In France, Ségolène Royal, the Minister of Ecology, is leading debate to have all chemicals banned in parks, schools and public places.

The International Agency for Research on Cancer (IARC), the specialised cancer agency of the World Health Organisation, came to the conclusion that glyphosate should now be classified as a carcinogenic substance in Group 2A (probably a cause of non Hogkins lymphoma in humans), based on "limited evidence" in human experiments and "sufficient evidence" in animal-experiments.

Limitations of our results

At the time of writing this paper our report is based on operator observations in the field. The use of saturated steam technology in conservation areas has been limited and whilst it has shown to probably provide some clear benefits, the method requires more rigorous structure in the set up of its application in order to determine efficacy, costs and environmental effects in comparison with other techniques.

What we will do over coming months and years

Over the coming months and years, Aus Eco Solutions, Weedtechnics, and other Weedtechnics licensees will continue to add to their collective knowledge of using saturated steam in both urban and conservation environments. This will include:

- Collect more data on impact on endangered flora and fauna species
- Collect data on reduction of weed species
- Continue to use saturated steam technology in wetland situations, including partnering with Midcoast Water on mid north coast of NSW for trial of the technology at Bootawa Dam revegetation project

We need more conclusive evidence on reducing seed banks particularly for specific species.

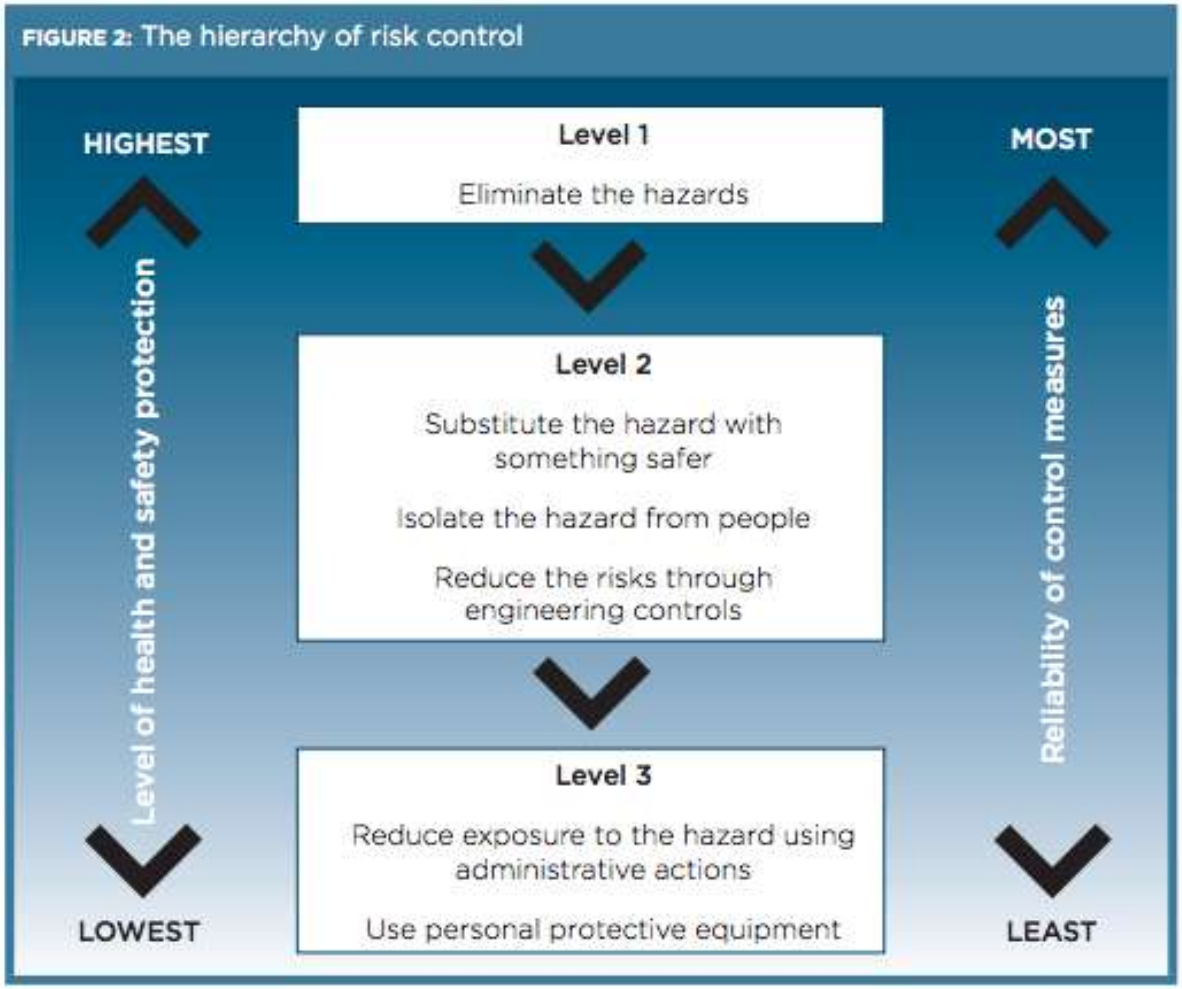
We need botanists/ecologists to interpret test plots - climatic versus thermal methods (ecological mosaic burning - dry thermal - wet thermal - no control) influence on seed bank germination versus removal of competition.

What we do know

In Australia our Work Health Safety (WHS) and Environmental Management Systems (EMS) systems clearly highlight more effective forms of hazard control should be managed using the hierarchy of controls.

Research that agricultural workers having higher incidence non-Hodgkins lymphoma could be argued that perhaps these workers did not wear recommended personal protective equipment (PPE), yet hierarchy of controls states that PPE is least preferred level of hazard control (refer Figure 2 from Workcover NSW "How to Manage Work Health and Safety risks Code of Practice")

We now have provided a viable alternative method with less impact than previous alternatives that removes off target toxicology risks to both native flora and fauna and agricultural workers, reduces labour costs and has potential to increase revegetation success. This method sits at the highest level of health and safety protection and the most reliable control measure according to the hierarchy of controls.



Source: Workcover NSW "How to Manage Work Health and Safety risks Code of Practice"

In the table below, some potential control measures to reduce off target toxicology risks have been presented:

CONTROL MEASURE	EXAMPLES
Eliminate the hazards	Ban use of herbicides; use hot wet thermal weed control
Substitute the hazard with something safer	Use brushcutter; hand weed; use bioactive "frog friendly" herbicides
Isolate the hazard from people	Use barriers in areas when herbicides are applied (i.e. public reservces)
Reduce the risks through engineering controls	Use closed system for mixing herbicides;
Reduce exposure using administrative actions	Use warning signs in areas when herbicides are applied (i.e. public reservces); safe work method statements; material safety data sheets; read herbicide label; check weather conditions, mix herbicides in open atmosphere not confined space; job rotation; prompt cleaning of residues from used containers; prohibiting eating, drinking and smoking near herbicides; provide handwashing / showering / laundering facilities to rinse off herbicides; training and supervision; emergency procedures
Use personal protective equipment	Wear overalls, aprons, footwear, gloves, chemical resistant glasses, face shields or respirators

Conclusion

The authors suggest that it is time to go back to the intent of the Bradley Method particularly for sensitive conservation sites with hydro thermal technology added to our kit bag for weed management and move away from the low cost "it's cheap and quick poison" approach. Thermal technology has numerous potential as well as demonstrated economic benefits and removes toxicology risks associated with Roundup and glyphosate products for people (particularly horticultural and conservation workers), flora and fauna.

Adopting fresh no chemical approaches such as hydro thermal weed management serve to support stressed ecosystems to regenerate themselves without residual off target toxicological effects.

References

Australian Bureau of Statistics (2002), *Measuring Australia's Progress (MAP)*, viewed 5/6/2015, URL: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Previousproducts/9A0C82D0F59158DCCA256BDC0012240D?opendocument

Australian Government Department of Environment, *Environment Protection and Biodiversity Conservation Act 1999*, viewed 11/05/2015, URL: http://www.environment.gov.au/epbc

Botta F et al (2009) Transfer of glyphosate and its degradate AMPA of surface waters through urban sewerage systems. *Chemosphere* Vol.77, Issue 1: 133-139.Department of Environment and Climate Change (NSW) 2007, *Management Plan for the Green and Golden Bell Frog Key Population at Kurnell.*

Department of Environment and Primary Industaries 2014, *Wetlands*, viewed 11/05/2015, URL: http://www.depi.vic.gov.au/water/rivers-estuaries-and-wetlands/wetlands.

Friends of the Earth Europe (2013) Introducing Glyphosate, the world's biggest selling herbicide. Rue d'Edimbourg, Brussels, Belgium.

Grice AC (2006) The impacts of invasive plant species on the biodiversity of Australian rangelands. *The Rangeland Journal* **28**, 27–35.

International Agency for Research on Cancer, World Health Organization (2015), *IARC Monographs Volume 112: evaluation of five organophosphate insecticides and herbicides*

Kristoffersen, O P. Rask, A M. Larsen, S U. (2007) Non-chemical weed control on traffic islands: a comparison of the efficacy of five weed control techniques. University Copenhagen

Lal.R (2004) Review article, Carbon emissions from farm operations. Carbon Management and Sequestration Center, School of Natural Resources , The Ohio State University, USA

Lee JR, Maggini R, Taylor MFJ, Fuller RA (2015) *Mapping the Drivers of Climate Change Vulnerability for Australia's Threatened Species*. PLoS ONE 10(5):e0124766. doi: 10.1371/journal.pone.0124766

Leferve L, Blanchet P & Angoujard G (2001) Non chemical weed control in urban areas. The British Crop Protection Council Conference: Weeds 2001 (ed CR Riches), 709 -714

McCallum, M (2007). *"Amphibian Decline or Extinction? Current Declines Dwarf Background Extinction Rate". Journal of Herpetology* **41** (3): 483–491.

Matarczyk J, Willis A, Vranjic J & Ash J (2002) Herbicides, weeds and endangered species: management of bitou bush (*Chrysanthemoides monilifera ssp. Rotundata*) with glyphosate and impacts on the endangered shrub, *Pimelea spicata*. *Biological Conservation* Vol.108, issue 2: 133-141.

Mesnage, R. Defarge, N. Spiroux de Vendomois, J. Seralini, G E (2014) Major Pesticides are more Toxic to Human Cells than their Declared Active Principles. University of Caen, Institute of Biology, Caen Cedex, France.

Newson, R J. Collins, G L. Waipuna International Limited, U.S. Patent Application for a 'Vegetation control method and apparatus', patent number PCT/NZ93/00035, filed Nov 19. 1997

Robin Mesnage, Nicolas Defarge, Joël Spiroux de Vendômois, and Gilles-Eric Séralini, "Major Pesticides Are More Toxic to Human Cells Than Their Declared Active Principles," BioMed Research International, vol. 2014, Article ID 179691, 8 pages, 2014. doi:10.1155/2014/179691

Ramwell, C. (2006) Environmental risk from using glyphosate on hard surfaces. Central Science Laboratory, York, UK. *Conference on Policies on Pesticide Use by Local and Regional Authorities.* Wageningen, Netherlands.

Rask, A M, (2012) Non Chemical weed control on hard surfaces: Investigation of long-term effects of thermal weed control methods. Forest & Landscape Research 52/2012 Copenhagen University.

Rask A M, Kristoffersen P (2006) A review of non-chemical weed control on hard surfaces. Faculty of Life Sciences, Danish Centre for Forest, Landscape and Planning, University of Copenhagen, Denmark.

Rask A M, Larsen S, Andreasen C, Kristoffersen P (2013) Determining treatment frequency for controlling weeds on traffic islands using chemical and non chemical weed control. Faculty of Life Sciences, Danish Centre for Forest, Landscape and Planning, University of Copenhagen, Denmark.

Stockard JD (1999) *Restoration of Wingham Brush 1980-1996*, Eleventh Australian Weeds Conference Proceedings

Stuart SN, Chanson JS, Cox NA, Young BE, Rodfigues ASL, Fischman DL, Waller RW, *Status and Trends of Amphibian Declines and Extinctions Worldwide*, Science 3 December 2004: 306 (5702), 1783-1786. Published online 14 October 2004 [DOI:10.1126/science.1103538]

Winer J (2014) *Holistic weed control practice for urban storm water catchments. Global trends, methods, limitations and cost benefits*, Stormwater 2014: 3rd National Conference on Urban Water Management, 13-17 October 2014

Workcover NSW (2011) *How to manage work health and safety risks Code of Practice*, 13.

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