Ecology and management of non-native *Poa annua* on sub-Antarctic Macquarie Island

A dissertation submitted by

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DECLARATION

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis and all sources have been acknowledged in this thesis.

Laura Kate Williams

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All samples were transported, stored and analysed in bio-secure conditions at the University of New England, Armidale, NSW and Australian Antarctic Division, Kingston, TAS and destroyed after use.

PUBLICATIONS ARISING FROM THIS THESIS

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Williams, L. K., Howard, C., & Scott, J. (in review) Change in the distribution of the indigenous grass *Poa litorosa* on sub-Antarctic Macquarie Island following the eradication of rabbits. *Papers and Proceedings of the Royal Society of Tasmania* (sideline project to PhD).

Williams, L. K., Kristiansen, P., Sindel, B.M., Wilson, S.C., & Shaw, J. (published online 4th May 2016) Quantifying the seed bank of an invasive grass in the sub-Antarctic: seed density, depth, persistence and viability. *Biological Invasions,* 1-14. DOI 10.1007/s10530-016-1154-x (see Appendix 2).

CONFERENCE PRESENTATIONS

Williams, L., Kristiansen, P., Shaw, J., Sindel B., & Wilson, S.C. (2013) Weeds down under: Invasion of the sub-Antarctic wilderness of Macquarie Island. *17th NSW Weeds Conference*, Corowa.

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Williams, L.K., Kristiansen, P., Sindel, B.M., Shaw, J.D., Wilson, S.C. (2014) Management of invasive *Poa annua* in the sub-Antarctic wilderness of Macquarie Island. *19th Australasian Weeds Conference*, Hobart.

Williams, L.K., Kristiansen, P., Sindel, B.M., Wilson, S.C., & Shaw, J.D. (2015) Management of an invasive grass in the sub-Antarctic: herbicide efficacy and selectivity. *13th International Conference of Ecology and Management of Alien Plant Invasions*, Hawaii Island.

Williams, L.K., Kristiansen, P., Sindel, B.M., Shaw, J.D., Wilson, S.C. (2015) Herbicides show potential in effectively and selectively controlling non-native *Poa annua* under sub-Antarctic temperatures. *Australian Turf grass Conference*, Hunter Valley.

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PREFACE

This thesis has been prepared for submission by publication. I have attempted to minimize repetition between the chapters, however some remains particularly in the methodology sections. This is due to the requirements of the journals, as well as the need for the papers to stand alone.

GLOSSERY OF TERMS

Alien species: With respect to a particular ecosystem, any species including its seeds, eggs, spores or other biological material capable of propagating that species, that is not native to that ecosystem (Monaco et al. 2002)

Invasive species: A species (usually alien) whose introduction leads to further spread and may cause economic or environmental harm or harm to human health (Monaco et al. 2002)

Native species: With respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred/currently occurs in that ecosystem (Monaco et al. 2002)

Southern Cool Temperate/Ocean Temperate Islands: Islands north of the Antarctic Polar Frontal Zone including the Falklands, New Zealand Shelf Islands and the islands and archipelagos of Tristan de Cahuna, Gough, St Paul and Amsterdam which have woody vegetation and a milder climate (Convey 2007)

Southern Ocean Islands: The islands of the sub-Antarctic together with the Cool Temperate Islands, between 37-60 °S (Convey 2007)

Sub-Antarctic islands: Islands forming a ring around the Antarctic Polar Frontal Zone between 46-54 °S, including Crozet, Kerguelen, Macquarie, Marion, McDonald, Prince Edwards group and South Georgia, where trees and shrubs are absent (Convey 2007)

Weed: A plant growing where it is undesired, or out of place (Monaco et al. 2002)

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ABSTRACT

Invasive species pose one of the greatest threats to the Antarctic region and consequently control is a priority to managers. To date, all successful eradications of vascular plants in the sub-Antarctic and Antarctica have been on small, restricted populations. Eradication or control is more difficult for widespread species, largely due to established seed banks. Information on the biology of the target species and the efficacy of control can increase eradication success. It is also important to assess the impact of control on non-target species.

One widespread invasive species in the Antarctic and sub-Antarctic under consideration for control is the grass *Poa annua*. For any potential eradication or control programs to be successful, information is required on the species' ecology and response to control. Therefore with the aim of informing future management of *P. annua,* my thesis focused on quantifying the ecology of *P. annua* on Macquarie Island and assessing the efficacy of physical and chemical control. This included assessing the impact of control on native plant species, and the mobility of glyphosate in Macquarie Island soils and potential off-target impacts.

I found that *P. annua* plants showed a perennial lifecycle, a common survival mechanism for sub-Antarctic plants, and they displayed considerable variation in growth forms across environmental gradients. *Poa annua* plant size and seed banks varied across Macquarie Island in response to *P. annua* cover and environmental variables. Larger plants and denser seed banks were found at low elevation sites with high *P. annua* cover, high animal disturbance and deep, sandy soils. The high cover of *P. annua* at these sites also suppressed native species diversity. Conversely, at high altitude, exposed sites with low *P. annua* cover and shallow soils, *P. annua* plants were small and seed bank densities were low or non-existent. Less than 3 % of buried seed remained viable for two years. Plants from all sites allocated most of their biomass to root material (60-80 %), likely to enhance persistence.

Physical control methods (scalping, hoeing, trimming, hand weeding) were ineffective on *P. annua* when applied once. Amitrole, clethodim, glyphosate, rimsulfuron and trifloxysulfuron sodium were all effective on *P. annua.* However glyphosate at 0.25 times the recommended application rate was the only treatment to also be selective. An integrated control program utilizing low rates of glyphosate to prevent further seed set followed by hand weeding of emerging seedlings is likely to be the most effective.

Glyphosate leaching from two Macquarie Island soils was low, less than 2.5 $\mu g\ L^{-1}$ from sand and 5 $\mu g\ L^{-1}$ from peat over 48 weeks in a column leaching trial. This equated to around

0.4 % of the glyphosate applied, with the rest strongly adsorbed to soil. Concentrations in leachates were well below regulatory guidelines and unlikely to impact on Macquarie Island biota, although further research is required, especially on aquatic flora and fauna.

My research provides a rare example of assessing the biology of an invasive species and the efficacy and impacts of a range of control methods. It shows that even within the Macquarie Island population, *P. annua* is highly variable in its seed production, growth habit and size and impact on native plant species. This variability may make management more difficult, however this knowledge into the species' ecology will be enable management of the species to be more efficient and effective throughout the sub-Antarctic. My research suggests that physical control methods are unlikely to be effective on this species at most locations, and that low rates of glyphosate show potential for effective, selective control, possibly in combination with hand weeding of low density sites. This research will assist managers to develop effective control programs for *P. annua* in the sub-Antarctic, but will also increase understanding of how invasive species perform in the sub-Antarctic and how information on the ecology of invasive species, and efficacy and impact of control can be used to inform management of invasive species throughout natural areas.