WRASP: A spatial weed risk assessment tool reveals critical variations in weed risks

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Summary Due to the overwhelming number and diversity of introduced invasive plants, coupled with limited weed management budgets, government agencies are typically required to employ systems to prioritise weeds for management attention. To help tackle this problem, an analytical protocol and spreadsheet tool was previously developed for post-border weed risk management (PBWRM). The popular PBWRM tool utilises a simple framework that ignores any spatial variation in risk factors within the geographical area of risk concern. However, invasive plants vary spatially in risk factors such as invasiveness, potential impacts, and feasibility of control. The PBWRM system requires the analyst to integrate each of these spatially-variable factors into a single risk score. This process is inherently subjective, difficult to implement and conceals the variations in weed risks. To address these concerns our trans-Tasman research team took the PBRWM logic and spatialised it, allowing weed managers to assess weed risks and management classes across geographical space. We illustrate this new spatial system using a case study of *Senecio glastifolius* L.f. in New Zealand, comparing the results of a spatial and an aspatial analysis of the risks it poses, and the consequent logical management options. The spatial portrayal of risks revealed locations of both higher and lower risk and suitability for management attention that were concealed within the aspatial weed risk scores of the current PBWRM system. The overall national level risk assessed using the spatial tool was also appreciably higher than that indicated by the aspatial scoring system. The spatial tool, WRASP, takes its name from Weed Risk Assessment SPatial. In New Zealand, WRASP forms part of an integrated set of tools for strategic weed management. This decision-support toolkit is described in Bourdôt *et al.* (2018).

Keywords CLIMEX, invasive plants, prioritisation tool, strategic weed management, Weed Risk Assessment, Weed Risk Management.

INTRODUCTION

Post-border weed risk management poses a set of costly and challenging problems to both public and private land managers. Taxonomically, exotic plants now dominate many national flora. For example, some 26,000 of the 46,000 known vascular plants present in Australia are exotic (Randall 2007). Of these, a little over 10% (~2700) are naturalised, and of these, approximately 30% (798) are considered a significant threat to the environment or agriculture. In New Zealand, the situation is similar, with the number of naturalised exotic plant species being similar to the number of indigenous species (~2500), and these being approximately 10% of the total number of introduced species (Howell 2008). Clearly, in any given jurisdiction there is a need to assess the threat posed by weeds as a step toward ensuring that appropriate management strategies are prepared and implemented for species posing the most significant threats.

Since the late 1990s, there has been a considerable interest in pre- and post-border risk assessment tools for invasive plants (Pheloung *et al.* 1999, Groves *et al.* 2001, Gordon *et al.* 2008). These tools provide a systematic method for considering the weed risk factors in both relative and absolute terms. The patterns of weed characteristics that are associated with weediness and invasiveness (Reichard 2001) form the basis for a spreadsheet-based point-scoring system to assess the likely weed risks plants might pose under different circumstances.

The Australian and New Zealand National Post-Border Weed Risk Management Protocol HB 294:2006 was developed on the back of a pre-border weed risk assessment system (Pheloung *et al.* 1999). It was developed into a standard protocol for use in Australia and New Zealand (PBWRM, Anon. 2006). Since that time the Food and Agriculture Organization have adopted it, and it has become an important tool in the management of weeds, being applied in Australia, New Zealand, Latin America, South America and North Africa (FAO 2011, Auld 2012). The logic of the system is clear, and the responses can be reviewed and critiqued; attributes that have doubtless contributed to it becoming popular throughout Australia, New Zealand and elsewhere. This system was updated recently to reflect developments in: '…risk management practice and in indicating the reliability of predictions; the management of contentious plants; and the translation of

WRM results into policy and management responses.' (Auld *et al.* 2012).

One of the inherent difficulties with using this type of aspatial scoring system is the need to account for the heterogeneous nature of the weed threats and the production or natural resource assets at risk.

This introduces a significant source of instability into the risk assessment method, in terms of the operator-specific or subjective nature of the factors taken into consideration when making their broad estimate. In the worst case they may simply apply a score transposed from a previous assessment in another region without considering the context-specific factors. The risk assessment results are highly sensitive to how the individual risk analyst transforms the heterogeneous risk factors into a single response (e.g. averaging or taking the extreme case) (see discussion and references in Barry and Lin 2010). A second consequence of the point based nature of the PBWRM tool is that each jurisdiction is required to complete the assessment *de novo*, resulting in wasted effort and inconsistent assessments.

Several authors have recognised that weed risks are inherently spatial, and some effort has been expended on developing spatial decision support systems for identifying weed management actions for invasive species (Crossman 2004, Crossman and Bass 2008, Januchowski-Hartley *et al.* 2011, Skurka Darin *et al.* 2011). The analytical frameworks of Januchowski-Hartley *et al.* (2011) and Skurka Darin *et al.* (2011) are each designed to optimise the allocation of resources to tactical weed management, rather than a broader assessment of relative risks. As observed in Auld (2012), they also require detailed information that may not be readily available for newly invading species, thereby limiting their utility for prioritising the management of weed communities that include invasive plants that are newly-arrived through to those that are well-established.

Here we describe the development of a spatialised version of the PBWRM tool to provide an analytical framework for identifying strategic weed management priorities. We compare the results of applying the spatial and aspatial versions of the PBWRM tool to assess the risks posed by *Senecio glastifolius* L.f. and the management options for it in New Zealand.

MATERIALS AND METHODS

Case study plant *Senecio glastifolius* (Asteraceae: Pink ragwort, Holly-leaved ragwort) is native to the Cape region of South Africa (Wells *et al.* 1986). It is an annual or short-lived perennial herb that grows to a height of 1–1.5 m and is presently increasing its distribution in both New Zealand (Figure 1) and south-western Western Australia (Hussey *et al.* 1997, Beautrais 2013). The foliage is palatable to livestock, and hence the plant typically invades ungrazed waste areas, roadside batters and coastal dunes. Its impact is regarded as limited in terms of alteration of natural biota in those ecosystems where it establishes (Williams *et al.* 1999). It has been the subject of localised but considerably labour-intensive management campaigns, commonly using manual removal.

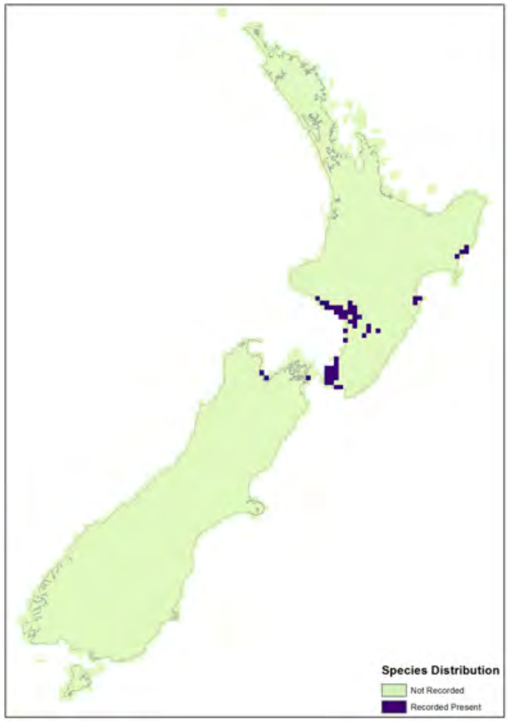

Figure 1. Current known distribution of *Senecio glastifolius* in New Zealand (source: herbarium records, Regional Council databases, Department of Conservation databases, and the observations of the authors).

Post-Border Weed Risk Management Protocol The Post-Border Weed Risk Management (PBWRM) protocol was published as an Australian and New Zealand Standard (Anon. 2006). It is based on 43 questions covering aspects of the history, biogeography, ecology, biology and impacts of a given species. The scoring system requires either ratings (0, 1 or 2) or yes/no answers to questions and is constructed such that equal weight is given to most questions. This aspatial system is implemented as an Excel spreadsheet. The PBWRM system was used to assess the risks and management options for *S. glastifolius* in the context of New Zealand.

Spatial weed risk management system (WRASP)
The logic of the PBWRM system was translated directly into ArcGIS (10.3) using model-builder. Where questions had answers that concerned the biology of the species and were spatially uniform, their non-spatial form was retained as in the current spreadsheet model (e.g. questions concerning dispersal mechanisms). Where a question could be answered spatially, the system prompts for a spatial dataset in raster form. The relevant spatial dataset for responding to each question is classified using exactly the same scoring schema as that used in the aspatial system.

RESULTS

The aspatial PBWRM system resulted in a risk score of 6, indicating that *S. glastifolius* posed a negligible risk to New Zealand as a whole. Combined with a feasibility of containment score of 27, the weed risk category was low and the corresponding recommended action was *limited action*. The risk score for *S. glastifolius* was substantially lowered because its potential distribution in New Zealand is limited.

In contrast, the spatial WRASP system indicated an average risk score of approximately 20. More importantly, it provided maps indicating that whilst most of New Zealand was under negligible threat, some areas were under low, medium and even high threat (Figure 2a, 3). The risk maps indicate that the greatest threats lie in the southern half of the North Island apart from the central highlands, and in the peri-coastal arc across the northern quarter of the South Island. The corresponding management actions range from *monitor populations* through most of the country through to *destroy infestations*, *protect sites* and *contain spread* (Figure 2b).

DISCUSSION

WRASP revealed significant sub-national spatial variation in weed risk and the technically prudent management strategy for the case study weed. Given New Zealand's legislative mandate for Regional Councils to manage pests, the WRASP system provides an economical and effective means for Regional Councils to identify risks and technically appropriate management strategies, perhaps as an input into a further economic screening process (Bourdôt *et al.* 2015). The single spatial analysis conducted here for *S. glastifolius* can be overlain by Regional Council (NZ) or Natural Resource Management Area boundaries (Australia) to Figure 3 highlight the specific risks to each management unit and the range of management options that

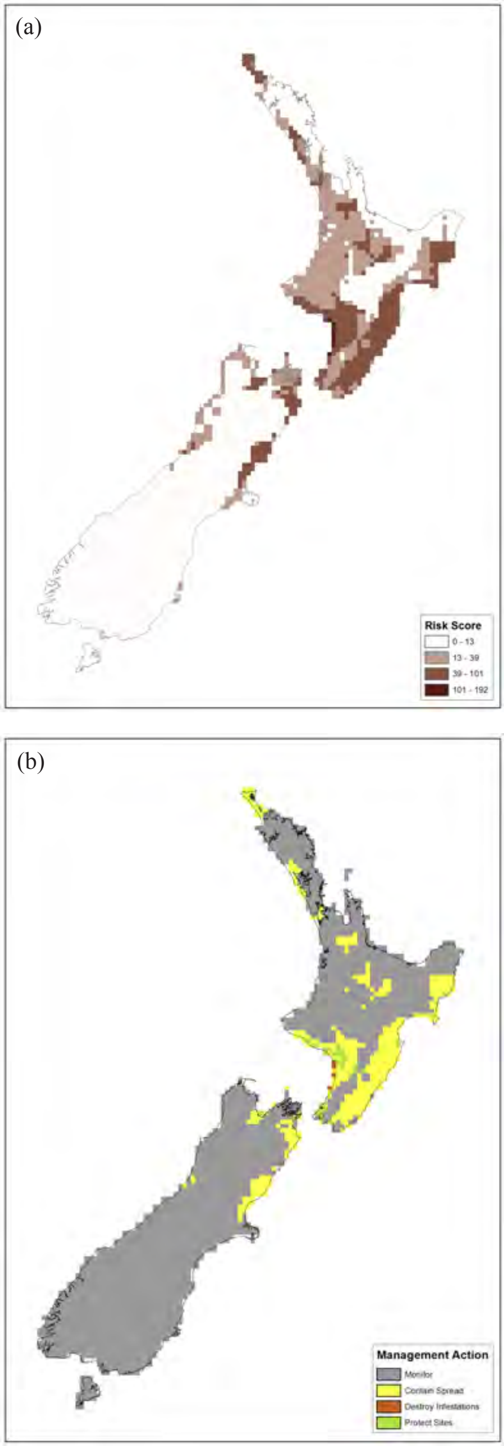

Figure 2. Spatialised weed risk (a) and management options (b) *Senecio glastifolius* in New Zealand developed using WRASP.

should be considered. At a glance, each biosecurity manager could immediately appreciate the threat patterns they are responsible for managing. Further, such a picture can highlight opportunities for transboundary coordinated efforts for weed management. For example, efforts to contain the spread of a weed in one region may stop or slow the spread to another region where it could generate significant impacts.

The fact that the single analysis can provide answers for all of the councils in New Zealand suggests that there is an economy of scales to be gained by undertaking the analyses in a centralised, or at least coordinated manner. The heterogeneity of the resulting risks also highlights the importance of considering how the risk factors vary across the country, and the folly of applying the results of the aspatial WRM system throughout the country.

The WRASP system is inherently more 'truthful' than the PBWRM; allowing the analyst to express their understanding of the various risk components using spatially-explicit evidence at a scale that is relevant for planning and executing strategic weed management. The degree of additional detail revealed in a WRASP analysis c.f. a PBWRM analysis is likely to vary depending upon the availability of information regarding the species being analysed, and the ability of the analyst to reveal the information spatially. WRASP reveals the outcome of combining the risk components in a spatially-explicit form. Conversely, the PBWRM requires the analyst to reduce the spatial complexity of the risk factors subjectively, increasing the potential for uncontrolled biases to be introduced into the analysis. At the extreme simplest limit, the WRASP model gives the same result as the PBWRM when no information is spatialised. In our case study we give examples of techniques for generating spatial datasets to answer questions in WRASP using common tools such as CLIMEX (Kriticos *et al.* 2015) to estimate the potential for spread of the weed.

WRASP is presently being made available to Regional Councils in New Zealand as part of a comprehensive Decision Support System (Bourdôt *et al.* 2018). When we have a number of completed spatial risk assessments we will turn our attention to a means of prioritising weeds at different levels of scale. Australia can, and should benefit from the development of WRASP.

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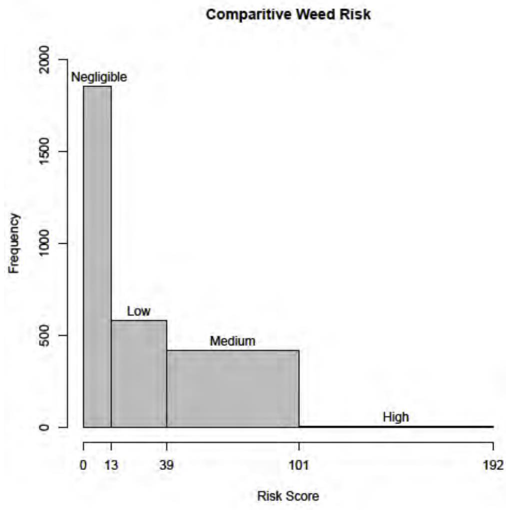

Figure 3. Histogram of risk scores for *Senecio glastifolius* in New Zealand developed using WRASP.

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